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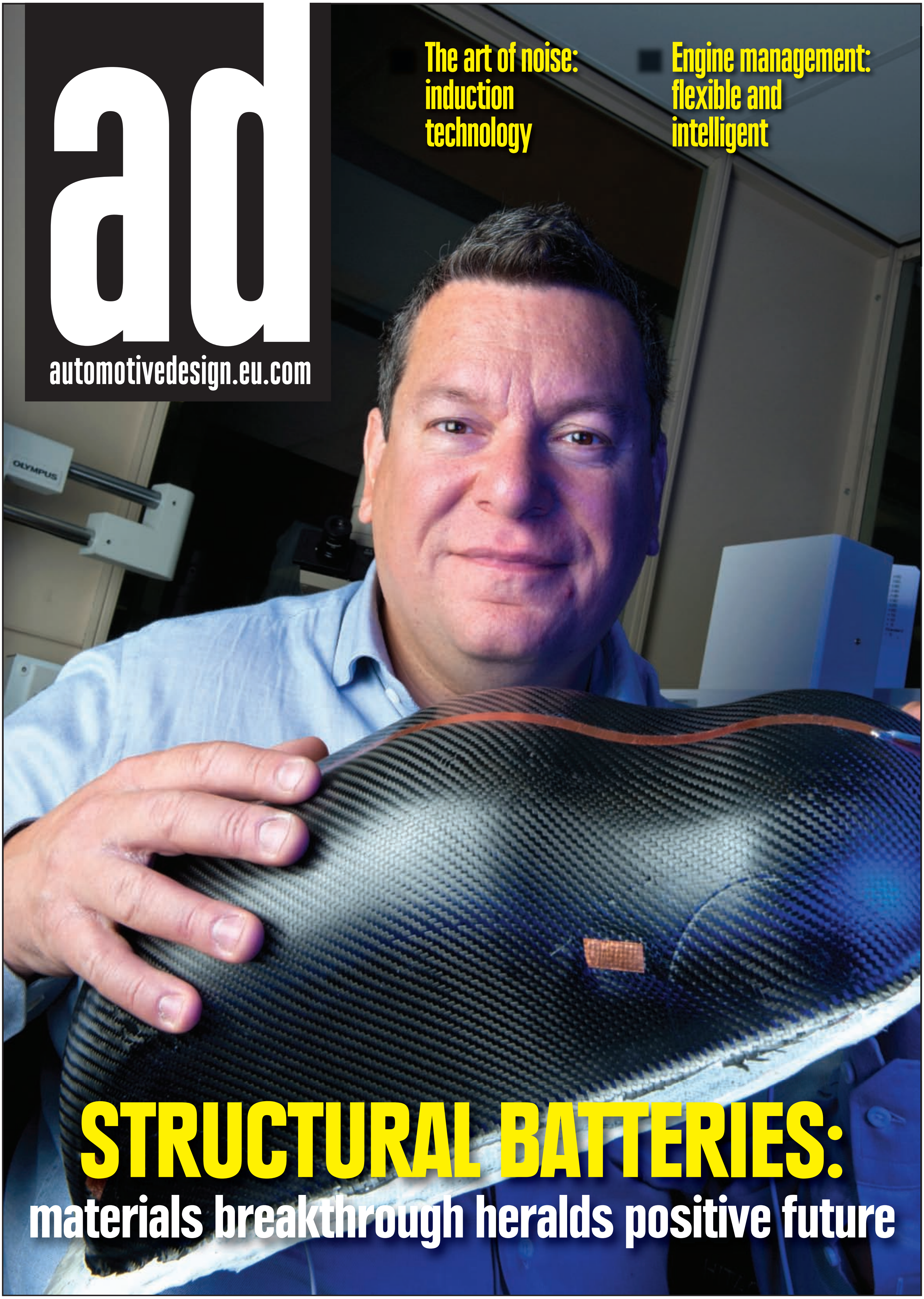

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STRUCTURAL BATTERIES:

materials breakthrough heralds positive future

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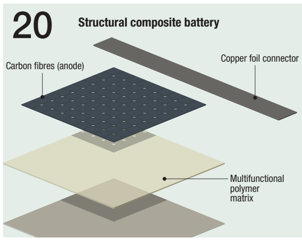
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Of all the Gall!

National motor shows are usually platforms for domestic manufacturers to puff their chests out with pride and wheel out a showcase of new products and concepts.

The biennial Frankfurt show is the ultimate expression of this, as Germany's big OEMs go head to head with ever larger stands, grandiose product displays and even mini test tracks.

And while Renault showed off its new Clio at the Paris Motor Show this month, it, Peugeot and Citroën were trumped by non-Gallic rivals: the increasingly dominant Volkswagen showed its seventh-generation Golf, GM trumpeted its Adam hatch that features some novel trim solutions, and South Korea's Hyundai and Kia displayed why they are serious threats to more established European marques.

Indeed, France's industry minister Arnaud Montebourg was openly hostile to the Koreans, accusing them of dumping cars on the market and exacerbating the problems being encountered by the domestic OEMs.

Whether that's true or not, it all goes to underline how fiercely competitive the European market has become, and that the successful manufacturers are those embracing new ideas and technologies to keep their products at the forefront of the customer's wish list.

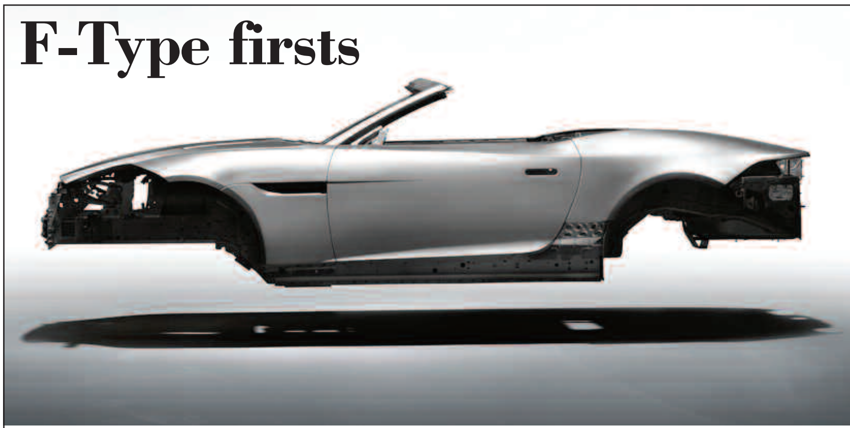
One such example is the increased use of aluminium in cars – up from 50kg in 1990 to 140kg today. Yet, even in five years' time, says Novelis vice president Roland Harings, aluminium will still only account for 3% of the world's vehicle output. The big growth, he predicts, will come from the USA that will eventually see it overtake Europe in the use of body-in-white and rolled products.

Even so, steel is fighting back, with cars such as the latest Golf using advanced steels to cut 23kg off the body weight.

One interesting observation made by several colleagues during the show was that the only electric vehicles to be found in Paris were on display in one of the halls; not a Twizy or any other EVs to be seen on the streets of Paris. What does that say about the rush towards electrification?

Ian Adcock, Editor in Chief

F-Type firsts



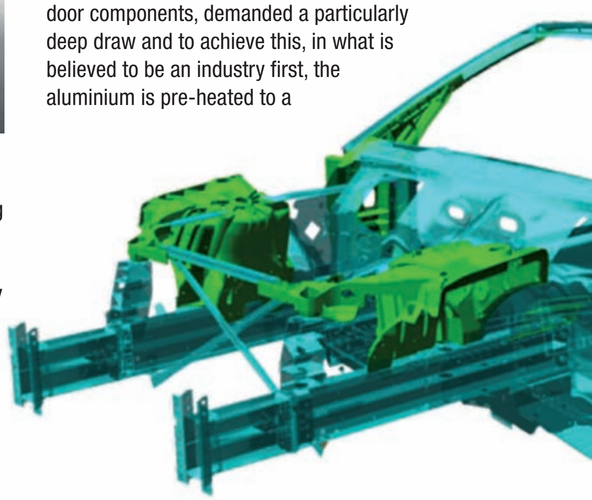
Jaguar's all-new F-Type sports car scores some notable automotive industry firsts in its aluminium construction.

Described by Ian Hoban, director Jaguar programmes, as the "fourth generation of our aluminium architecture", the new two-seater has a 10% increase in overall torsional stiffness compared to the XKRS which was the development team's internal benchmark. For example, the lateral stiffness of the front suspension mounts has been increased by 30% over the XKRS and the suspension knuckles by 24%.

Core to that integrity are the 'B' post nodes that are not only essential load carrying parts attached to the heel board but, also, mount the convertible hood mechanism and the roll-over protection hoops. In addition they have a dimensional role to perform with tolerances of ± 0.8mm between the castings and the pressed wheel arch inner panel. "To get the structural performance we need it has to be a perfect match between the two," commented Hoban.

Frontal impact loads are managed through the longitudinals and into the base of the 'A' posts and out through the sills. "That's important," explains Hoban, "because if you have the crash structure under the car that puts the occupants up, so all the crash structure goes out and round the car protecting the occupants and offering side impact protection as well."

To achieve the door's distinctive barrel-like profile, as well as reducing the number of door components, demanded a particularly deep draw and to achieve this, in what is believed to be an industry first, the aluminium is pre-heated to a



Fully connected

BMWs recently announced 'ConnectedDrive' will, the car maker claims, connect driver and car to the rest of the world. At the heart of the system is a 2 DIN head unit, described by Harman, its developer, as the most advanced in the world.

According to Harman, the unit used in the BMW incorporates a range of industry firsts, including intuitive Office synchronisation, and the ability to record voice memos and dictate emails.

Rich feature content meant packaging the DVD mechanism, 200GB HDD, amplifiers, processors, tuner and optical network components within tight confines of the magnesium chassis. Harman has worked with a number of technical partners to maximise efficiency. "We looked at materials, power management and components to achieve this," says Kelei Shen, vice president, global engineering, "with our patented GreenEdge technologies providing many of the answers."

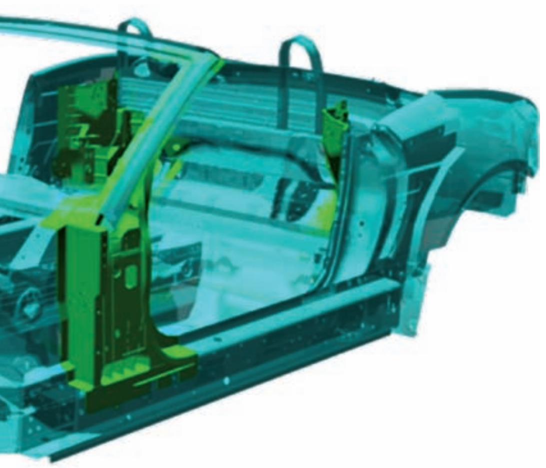
Shen's engineers specified NVIDIA's EMP9 graphics processor, coupled to a 1.3GHz Intel processor for increased clarity and detail in the visual interface; while Nuance's Dragon Drive enables the driver to dictate and send short emails and texts, and record voice memos in six languages.

As the 'hub' of ConnectedDrive, Harman set itself a clear aim for seamless connectivity. "We created a proprietary piece of middleware to support Bluetooth, WLAN, Edge and UTMS," says Shen. "For the end user, Bluetooth pairing is

Kelei Shen, vice president

temperature of around 260°C before being stamped.

Unlike steel, aluminium has a 'memory' leading to rebound and challenges in achieving crisp swage lines. Previously radii of 15-20mm has been the norm but, in what is thought to be another industry first, Jaguar has achieved 8mm on the bonnet hemming by striking the material twice whilst it is in the press.



significantly simpler and you can connect two phones. Above the middleware, we integrated real-time traffic and internet radio into the onboard applications to let the end user enjoy the content with minimum effort."

The unit is part of Harman's strategy to serve all levels of infotainment with three core platforms – entry, mid and premium. The BMW 7 Series is the first car to receive the unit, with the 3, 5 and 6 Series following.

Daimler-Renault engine collaboration

Daimler and the Renault-Nissan Alliance are collaborating on two new projects to accelerate development of fuel-efficient powertrains.

The new engine is a jointly developed 4-cylinder petrol family, co-led by Renault and Daimler, that will debut in 2016. The direct-injection turbocharged engine will feature state-of-the-art technology in a compact package. It targets a significant improvement in fuel economy, as well as low emissions.

In the new transmission project, Daimler grants Nissan a licence to manufacture automatic transmissions, using Daimler's latest transmission technology for Nissan and Infiniti vehicles, starting in 2016.

News in brief

Turbochargers' sales boost

The number of passenger vehicles with turbocharged engines is expected to increase globally by 80% to 36 million passenger cars by 2017, according to projections released by Honeywell at the Paris Motor Show.

The United States, India and China are expected to lead the global growth, as consumers and automakers in these markets search for ways to get ever greater efficiency, whether through petrol or diesel engines. In Europe, where turbochargers are already on two-thirds of passenger vehicles, the technology is expected to gain even more ground, as car makers meet more stringent CO2 emissions requirements.

Stuck on you

Loctite 403, 408 and 460 are three improved instant adhesives from Henkel that can be used for bonding virtually any materials.

The primary difference between them is their viscosity: while Loctite 403 has very high viscosity, at 1200 mPa s (millipascal-seconds), Loctite 460 offers low viscosity (40 mPa s) and Loctite 408 very low viscosity (5 mPa s).

New Tecasint polymides

Ensinger has launched a range of new semi-finished products as part of its 4000 series. They are particularly suited to applications entailing unusual demands on the oxidative stability of the materials. Highlights include type TECASINT 4111. With thermal dimensional stability of 470°C, in accordance with HDT/A, this polyimide offers up scope not only for whole new uses, but also for improving the efficiency and service life of existing applications.

BASF and Durr analysis

Integrated processes without primer or wet-on-wet aplications offer significant environmental and cost savings to OEMs and boost eco-efficiency, say BASF and Durr, following a holistic analysis the two recently performed. This allows both companies to individually improve the eco-efficiency of the OEMs' coatings systems at their manufacturing plants.

Aisin launches 8-speed auto

In a bid to improve efficiency and to compete with ZF's upcoming nine-speed front drive transmission, Aisin has developed its own advanced transverse FWD automatic, the TG-80 LS, with eight forward ratios.

Aisin is the world's number one supplier of automatic transmissions and was the first to launch an eight-speed transmission, on the rear-drive Lexus LS460 in 2008 – at a time when other companies offered no more than six speeds. The new FWD eight-speed uses the same geartrain concept as the premium RWD unit, says Aisin; changes over the existing six-speed unit include an additional clutch pack and modifying one of the planetary gearsets to accommodate the extra ratios. Overall weight is quoted at 96 kg, including lubricant.

The two extra ratios allow first gear to be 19% lower than that on today's six-speed, while eighth is 15% higher than the old unit's sixth. With the new, broader ratio spread and improvements to the oil pump and a reduction in other drag losses, Aisin is claiming a 6.5% improvement in mpg on the US combined cycle.

Two versions will be available, rated at either 350 or 500 Nm torque capacity, and suitable, says Aisin, for cars in the 3.5 litre class. No launch application has been announced.

Aisin is also presenting a revised medium-capacity CVT, again for FWD, claiming reduced fuel consumption, thanks to a new valve body and oil pump, as well as a new CVT fluid.

Sustainable tyre debuts

Bridgestone displayed a concept tyre made from 100% sustainable materials at the Paris Motor Show.

The tyre represents an example of Bridgestone's use of advanced materials technologies to achieve the commitment of using 100% sustainable materials in its tyre manufacturing for 2050 and beyond.

The concept tyre is the result of collaborative efforts with a number of resources, including academia. In order to achieve the level of 100% sustainable materials, Bridgestone is diversifying the regions where it produces natural rubber and also expanding the range of reinforced plant fibres it uses. Additionally, fossil resource-based components, such as synthetic rubber, carbon black and rubber compounding agents in the tyre, were synthesised from biomass.

GM's new A-sector challenger, the Adam, launched at the Paris show, comes with a bewildering array of options – with a potential million-plus combinations.

Two factors that contribute to this are patented clip-on wheel trims that can be used to personalise the hub spokes.

The second, according to director of interior design Elizabeth Wetzel, is the first automotive industry application of back-lit fascia, using LEDs. Additionally, the fascia inserts – along with elements of the centre console trim – can be replaced to freshen up the interior.

When Good Enough Is Not Good Enough

It's a tough, competitive world. If you let your guard down for a second, your competition could knock you out of the game. So you've got to keep finding ways to get better, faster, more accurate. That's the way we think at AR, and that's why our customers welcome our new products and new technologies. We can help you gain a competitive edge with innovations like the following:

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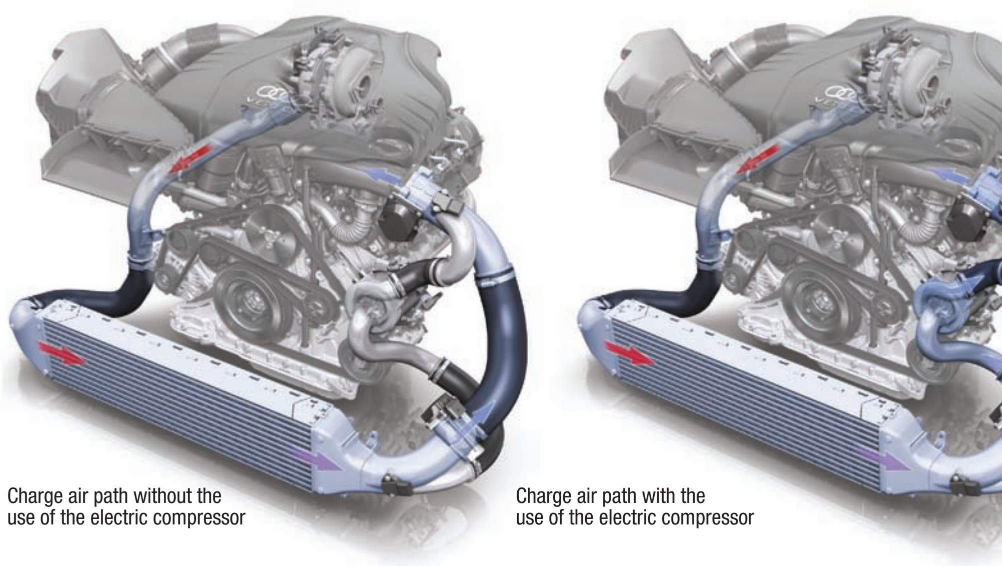
Blown away

Audi V6 TDI with electric Biturbo



Charge air path without the use of the electric compressor

Charge air path with the use of the electric compressor

Audi is working with three suppliers, including Valeo, to determine which electrically-assisted turbocharger it will put into series production within the next two to three years, according to the company's Martin Schüssler, speaking at a recent technology presentation.

The current development engine is based on Audi's bi-turbo three-litre TDI V6 and, although reluctant to give specific power outputs, Audi said that, from a standing start, the revised engine would be three car lengths faster than the standard V6.

Instead of a turbine wheel driven by the exhaust, this is an auxiliary charging stage, arranged in line with the gas-driven turbocharger. It integrates a small electric motor that can accelerate its turbine to very high speeds in an extremely short time; Audi would go no further than saying it reached operating speeds of "about" 70,000rpm in three-tenths of a second.

The electrically driven compressor is placed after the main turbocharger and intercooler in the charge air path. In most operating states, the charge air is routed around it via a bypass. However, when the flap integrated in the bypass closes – ie, when the main turbocharger's energy output is low – the air is directed into the electric compressor and is compressed there a second time. It also has the beneficial side effect of lighting the catalytic convertor off earlier.

The compressor requires about 5kW to power it, energy that will be harvested through regenerative braking via a 42V system and stored using lithium-ion batteries or super capacitors.

Unlike the Valeo-Renault demonstrator featured in last month's issue, where the electric compressor was used to aid a downsized engine, the Audi application is more about raw power, the A6 quattro with its eight-speed auto stepping off the line with alacrity under full bore acceleration. Even cruising in higher ratios and initiating kick-down resulted in far sharper response than you'd expect from a normal blown diesel V6.

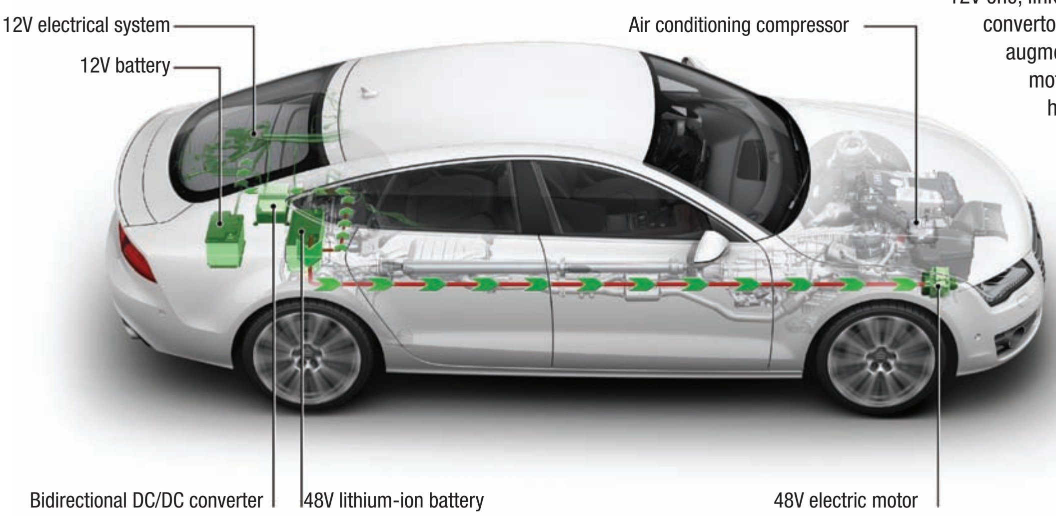
Just coasting

Using its new predictive efficiency assistant (PEA), Audi has cut fuel consumption of its developmental A7 Sportback 3.0 TFSI iHEV by 12% over a 61Kms route, increasing the journey time by only two minutes or 3%.

PEA takes inputs from the navigation system's predictive route data, including gradients, speed limits and road conditions, as well as the car's status – number of passengers, if there's a roof box or trailer – for the engine management system to calculate whether it is better to drive the route with the drivetrain connected or disconnected. It is assisted by the adaptive cruise control (ACC), which monitors traffic ahead of the vehicle, using a radar sensor.

Audi iHEV – intelligent hybrid electric vehicle

Energy flow without engine running (coasting, engine off) Climate retention system



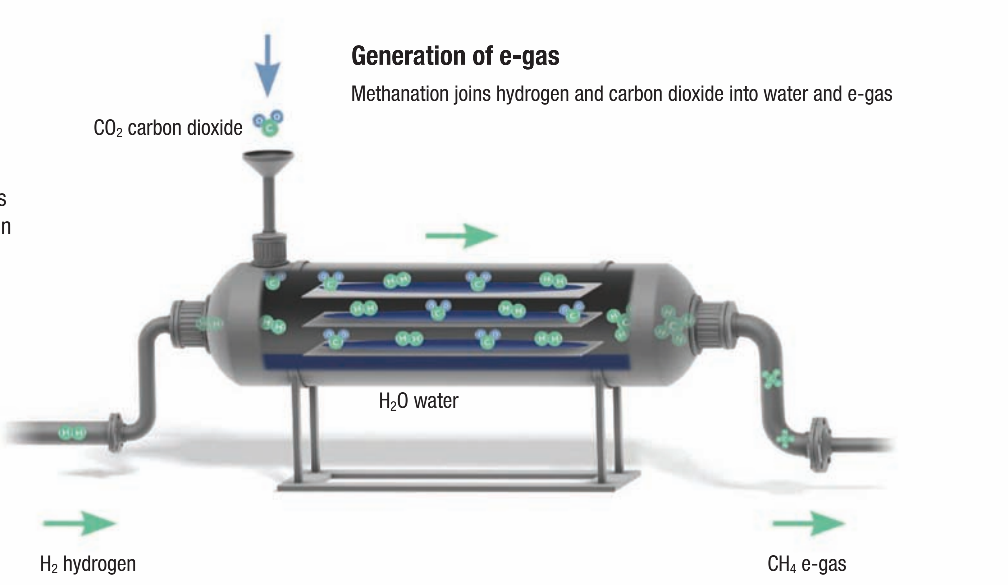
The A7 Sportback 3.0 TFSI iHEV uses a 48V lithium-ion battery, as well as its standard 12V one, linked by a bi-directional convertor, with the three-litre V6 TDI augmented by a 10kW electric motor. The standard alternator has been replaced with a stop-start 48V electric motor, using a Vee-belt to restart the engine within 0.4-0.6secs. While the engine is switched off, energy is supplied via a high-cycle-strength 48V lithium-ion battery, maintaining the heating, ventilation and air-conditioning performance, while the brake system has sufficient capacity for

Stepping on the gas

Audi is partnering SolarFuel to open the world's first facility to convert renewable electricity and CO_2 into a synthetic natural gas that can be fed into the natural gas network on an industrial scale in Wertle, Germany. It will go on stream in the third quarter of 2013.

The facility will produce about 1,000 metric tons of methane a year and, in the process, it will chemically bond 2,800 metric tons of CO_2.

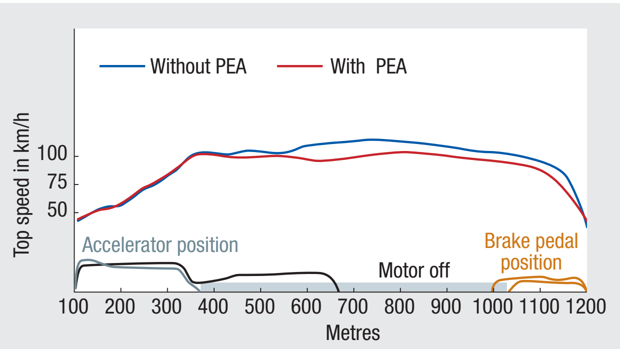
Audi's main innovation is combining hydrogen with CO_2 in a methanation system (downstream of electrolysis) to synthesise renewable methane – Audi e-gas that can be fed into the natural gas network for storage.



The input material for the biogas plant is not energy crop plants; rather it is organic waste, avoiding any competition with food production. The CO_2 itself is a waste product of the biogas plant that would otherwise be released into the atmosphere and is used as a feedstock for the fuel. This makes Audi e-gas a climate-neutral fuel – when it is combusted in the engine, the amount of CO_2 emitted is equivalent to that consumed by the e-gas facility beforehand.

The German energy industry could also benefit from the concept over the mid-term, because it must address the open issue of how to store eco-electricity efficiently and independent of location. When a lot of wind is blowing, electrical overcapacities from wind farms could be converted to Audi e-gas and stored in the public gas network – with its 217 Terrawatt-hours of energy capacity, it is by far the largest energy storage network in Germany. It would then be possible to convert the energy from the gas network back into electricity, when needed.

Audi displayed an A3 TCNG and plans to launch a second model, based on the A4, in 2015.



two full emergency stops before the engine is automatically restarted to boost the system back to full capacity.

When the predictive efficiency assistant is combined with the iHEV system, the freewheel function is activated and the internal combustion engine switched off (freewheel – engine off). The restart is performed by a powerful electric motor located in the belt drive.

The only slight flaw discovered during a brief drive of the prototype was a faint thud and jolt as the engine was kicked back into life, but otherwise it was a seamless experience, and it quickly became second nature to read the road and traffic conditions ahead, in an attempt to maximise coasting and reduce fuel consumption. At motorway speeds, Audi engineers maintain the car could coast for upwards of a kilometre with the engine switched off.

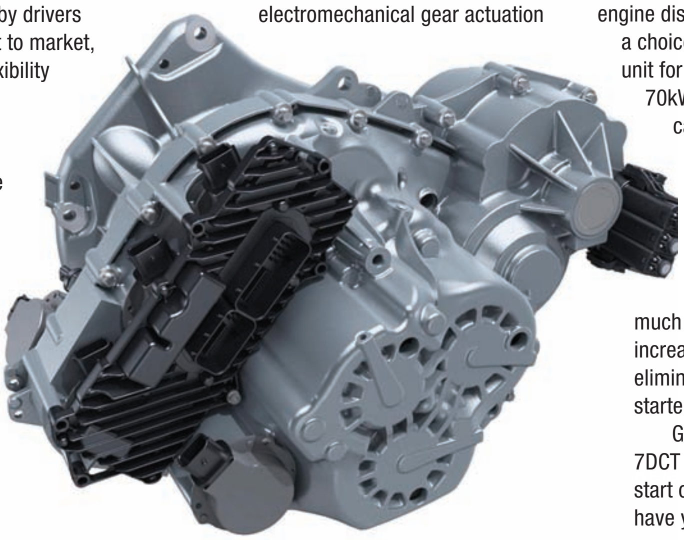
Getrag's next-generation DCT

With auto industry growth being increasingly driven by the expansion of sales in developing markets, manuals and DCTs will experience the strongest demand increase among transmissions.

Presenting Getrag's new generation of seven-speed DCTs shortly before the Paris show last month, company executive vice president of sales and marketing Bernd Eckl noted that the attributes wanted by drivers differed significantly from market to market, making it essential to build in flexibility within the new modular global transmission platform.

The seven-speed wet clutch 7DCT300 is the core model in the new family of modular transmissions: significant commonalities are shared with the smaller, six-speed 6DCT250 and its new lower-torque derivative, the 6DCT150, as well as with the high-capacity 7DCT500 and a variety of derivatives incorporating hybrid drive.

The 7DCT300, says VP of product development Ernest DeVincent, is a response to market pressures, including the need for greater efficiency, lighter weight, lower cost and improved refinement. Moving to seven speeds enables an expansion of the gear ratio span to 8.5, contributing to an overall fuel economy improvement of 4%, compared with the six-speed dry clutch DCT250.



The new transmission's design takes in electromechanical gear actuation and electrohydraulic actuation for the wet clutches. Stop-start functionality and park lock are built in, and cooling is via an on-demand electrical fluid pump. Significantly, the lubricant is low viscosity, fill-for-life.

Closely related is a family of hybrid spin-offs. With the basic transmission already offering micro-hybrid capability by allowing extended stop-start and 'sailing' with the engine disengaged, the hybrid 7HDT300 adds a choice of integrated e-machines: a 48V unit for mild hybrid operation or a 250V, 70kW motor for full or plug-in hybrids, capable of up to 130 km/h.

The same e-machine kit can be applied to both the 7DCT500 and the 6DCT150, and Getrag points out that, in contrast to both AT- and CVT-based hybrids, the TorqueSplit DCT hybrid is much higher in efficiency, suffers no increase in transmission length and eliminates the need for a conventional starter motor.

Getrag's product roadmap shows the 7DCT entering volume production at the start of 2015, but no launch customers have yet been announced.

The revolution starts here

The smartphone's role in the control and functionality of future cars and other vehicles could be about to get a lot more complex and highly integrated, according to Christof Helmis, Nokia's VP map platforms.

With the advent of 4G Long Term Evolution (LTE), Helmis predicts that not only will vehicle-to-vehicle (V2V) connectivity increase, but that connectivity will, in future, be centred on the individual, rather than the vehicle itself. "Connectivity will revolutionise mobility. We're just at the very start. Customer behaviour will change, with novel services and purchase patterns, etc. And new generations will have very different demands of the vehicle than we do today," he told *Automotive Design* at the Paris motor show.

According to Helmis: "There are scenarios that strongly believe the smart phone or tablet will replace the car's infotainment system. It's probably a little bit of an analogy between the pc, laptop, mobile computer and the mainframe, in that all still exist, as they all serve a very clear purpose. So, yes, you will see more people relying increasingly on a personal device; and the smartphone is super personal, carrying a lot of stuff and having access to the cloud. A lot of personal services will reside in that device and will be carried into a vehicle."

But it's in the field of engine and vehicle management that these smart devices could have their biggest impact. Nokia already has a function called 'My Commute' that automatically learns how individuals drive and their regular commutes. "Having this learning will give you better prediction than on a very anonymous basis, because the system knows your routine. This is clever learning for the individual, rather than having a very generic prediction level," explains Helmis, adding: "Fuel savings could be even greater than Audi's predicted 10% (see page 10), because it's a more active system that could suggest a longer, but more efficient, route avoiding jams, etc. We see a strong interest from consumers wanting better fuel efficiency."

Helmis even suggests that, with new content layers such as Advanced Driver Assistance Systems (ADAS), curvature and

Christof Helmis predicts increased phone connectivity

slope data, the mobile device could communicate directly with the car's powertrain management systems to fine-tune it for optimum fuel efficiency or power harvesting. "ADAS will slowly converge from multiple angles – for instance, from efficiency gains and the behavioural patterns of the driver, using a personalised navigation app."

Democratisation of Technology

Andreas Schamel

CV

Andreas Schamel was appointed managing director of the European Ford Research Centre, based in Aachen, Germany, as well as chief engineer Powertrain Research and Advanced Engineering Europe on 1 February 2009. In addition to his position as managing director, he assumed the lead role as site manager of the Ford Research Centre, Aachen, and has overall responsibility for the operational business.

Prior to his current assignment, Schamel was chief engineer, Engine Research, Research and Advanced Engineering for Ford Motor Company, based in Dearborn, USA.

Previous to this position, he was manager Gasoline Powertrain Europe, based in Cologne, Germany, also leading the development of Gasoline Direct Injection Technology for Ford.

He has been with Ford since 1987, starting in component analysis computer-aided engine engineering. His background in engines spans 21 years, with primary qualifications in Mechanical Engineering, an MSc. in Advanced Automotive Engineering and a PhD focusing on valve spring dynamics, both from Loughborough University of Technology, England.

Born in Bonn in 1962, he is married, with three children.

Ian Adcock caught up with Andreas Schamel, managing director of the European Ford Research Centre, at the recent Future Transport Challenge to get an insight into the brand's engineering strategy

The 'Democratisation of Technology' sounds like one of those tag lines dreamt up by a smart advertising or marketing executive that has no real meaning behind it – all froth and no substance. But to Andreas Schamel and his colleagues at Ford, it encapsulates an engineering strategy that will bring real-world benefits to Ford customers, wherever they are.

"We have this tag line, 'Democratisation of Technology,' which delivers something for the volume customers and is accessible," he states. "A good example of that is EcoBoost; it's significantly more expensive than a naturally-aspirated gasoline engine, but it does pay back the customer and there's still quite a gap, in terms of cost savings, to a conventional diesel engine."

Other examples Schamel cites are the introduction of technologies like automatic speed management, lane departure warning, active city stop and the recent launch of Sync into Ford's European range. In many cases, these technologies, once the preserve of more expensive cars, are now filtering their way down the price chain, increasing their accessibility to a wider audience. And, in Ford's case, that means a market spanning the globe, from Brussels to Beijing, Brisbane and Boston.

Electrification's future

With the recent launch of the Ford Focus Electric, it seemed like an opportune time to get Schamel's thoughts on vehicle electrification and its high costs, compared to internal combustion engines. "We're still talking about thousands of dollars per kW/hour, even if we're heading towards $500-600 – so, 50%. I wouldn't say that's out of the realms of possibility. The other piece that is difficult to judge is what are the boundary conditions that suppliers and OEMs are looking at? Are they purely just looking at the cell or at the installed system, including the battery pack and cooling, safety, as there are efficiencies to be gained there as well. When those figures will be achieved depends on how the market picks up and volumes," he states.

"When you look at the production and conversion chain, electricity is the most expensive energy we have, the most valuable. Okay, if it's from nuclear, it's a different story, if not necessarily a better story. Electricity is a fairly high value and the reason why it's cheap to drive an EV today is because there's no 70% tax on it.

"It's locally emissions free, to be fair, so, for congested areas, it doesn't pollute. But somewhere there's a green plant, so you make it as clean as possible to get the dirt out of the cities," he explains, before suggesting to "stay tuned" over the coming months about developments on fuel cell vehicles.

Traction attraction

One alternative power source that seems to be steadily gaining traction, both as an alternative to hydrogen and as a fuel in its own right, is compressed natural gas (CNG). "CNG is an interesting alternative to hydrogen. Really, the challenge with renewable energy sources is that you need a storage system of some kind, so the conventional storage system doesn't really apply to mainstream Europe. You can also produce artificial, synthetic CNG by extracting hydrogen and carbon, and reassembling it. And that could be an onsite production and storage next to windfarms. The advantage versus hydrogen is that you have the transport system available, as CNG is compatible with natural gas, so you have a distribution system at no extra cost.

"We're watching the uptake on natural gas and it's potentially interesting. It's already of interest in some markets and might become more so in the mature markets of Europe and North America."

The modifications required depend on the engine's architecture, he points out. "One of the problems with natural gas is that it's a dry fuel – it doesn't have any lubricity coming with it – so it's pretty difficult on the valve train and other engine components. Then there's the separate question of achieving maximum efficiency. Natural gas becomes interesting if you have the infrastructure available so you can rely on natural gas being the mono fuel for that vehicle.

"You could maybe have a small gasoline tank, which then provides a limp-home functionality, but then you're talking about engines that are significantly optimised for natural gas; getting into natural gas direct injection, very high compression ratios. Because natural gas is extremely knock resistant, you can get to diesel – or better than diesel – efficiency. But such an engine can't run on gasoline or, if they do, you run it in boost-deprived, limp-home mode."

Shifting the balance

The forthcoming Euro 6 emissions will, predicts Schamel, shift the balance point between diesel and petrol to where diesel makes sense in heavier vehicles than where it is today. "If you look at the Transit commercial range, it's almost exclusively diesel, whereas the entry-level Fiesta is 90% gasoline. That balance point will shift with the expensive after-treatment technology that will be required."

But this doesn't herald the eventual demise of the diesel engine. Quite the contrary, claims Schamel, thanks to the re-emergence of interest in 42V and 48V systems, as he explains. "We're looking seriously at 42-48V, but more in the context of diesels than gasoline. The attraction there for diesels with a higher voltage level is that you don't have the same safety concerns as you do for the high voltage for hybrid or full EVs. What you can realise with those higher voltage levels is a 10-15kW electric machine that's sufficient to recoup the energy from braking. It's enough to harvest that, but insufficient to do what the gasoline engine needs with its operating

points or scheduling. A diesel engine doesn't need that, because it's more efficient across the map.

"If you look at a gasoline engine and the specific fuel the engine consumes at any given operating point, the grams per kWh – effectively in mid-speed/mid load area – you have a fairly small island where the engine is efficient. And the more you divert from that island to peak power points, where you get enrichment, it becomes very inefficient. The bottom end, idle, is also very inefficient because of pumping losses.

"With a lot of technology like downsizing and boosting, you avoid the enrichment and widen that island somewhat, but you still have that inherent characteristic of the gasoline engine, which is that it's only good in the mid-range.

Diesel efficiency

"Diesel's efficiency map is a lot flatter; that's why customers like them for motorway driving, because they're so much more efficient. Even if it's higher powered, you don't get into excessive fuel consumption.

"What a hybrid does on a gasoline engine is allow you to switch the engine off and start electric with a really low load, so you avoid that inefficient operating point and

support the engine when you would otherwise move into a higher speed, less efficient, range. Effectively, what you do with your 50-60kW machine is you make sure it's kept in its most efficient zone. You can coast electric, do parking manouevres and also city driving for a limited time."

Meanwhile, Schamel believes the mild hybrid, on the diesel side, has an interesting future. "If downsizing is one trend, then light weighting – taking the mass out of vehicles – is another."

And although he concedes that aluminium closures and the increased use of lightweight steels are on Ford's road map and enablers for downsized chassis components, and are "clearly a target," he also warns: "[While] we're looking at all the new materials and production methods for aluminium, we need to keep in mind the assets available, and the scale and cost of turning them over into a new technology across the globe." So don't expect to see an aluminium-intensive Mondeo or Focus on the road any day soon.

Schamel might be based in Europe, but Ford's engineering strategy means that he has to have a global vision that ensures new technologies are just as relevant to all drivers, irrespective of where they live.

Intellectual property – protecting our knowledge

Professional associations like SAE International face an ever increasingly complex set of opportunities and challenges. The explosive growth in technology enables the lifeblood of our organisations – our intellectual property (IP) – to be offered in the most convenient and technologically advanced ways possible.

However, these same technologies also enable intellectual property to be shared and spread illegally, serving to cheapen its content and short-changing the people who properly purchase it.

It's a dilemma with no easy answers, but one that we, as an organisation, are proactively addressing.

SAE International's IP protection programme has several components. For starters, there is the matter of digital rights management (DRM). New DRM technologies to help protect IP are being developed and introduced on a continual basis – including watermarks and threshold tools that monitor download rates and times, and automatically shut off access when preset parameters are reached.

Such technologies require a balancing act between 'thievery protection' and 'product functionality'. In short, we want to make sure that IP can't be stolen; but, at the same time, we don't want the protection devices to make it hard for legitimate users to access the information. SAE International has created a team that will periodically review DRM best practices and consider how they can be implemented into our IP products.

Another component that we consider is enforcement of DRM and copyright issues. SAE International regularly requires websites to take down illegally posted IP. When that doesn't work, we consider legal action and have taken such steps in the past. We are committed to doing what is needed to ensure that SAE International's IP is not being illegally accessed or shared.

There are other components of our IP programme that may not be as obvious, but are nonetheless effective. Two of these include strategic alliances and lobbying activities.

One of SAE International's greatest strengths is our ability to collaborate with other associations and groups around the world. There are many opportunities to help protect IP through such partnerships. Collaboration, especially so with organisations from other countries, can help reduce overall expenses for new technologies and share best practices. SAE International already works with groups and holds regular teleconferences to discuss infringement issues.

Regarding lobbying, while SAE International is not in the business of creating policies or regulations, we do work to inform those who do. Several actions are under consideration by the US government, with regards to protecting IP from online piracy, and we are engaging the appropriate committees and groups to serve as a resource for accurate data and information.

> It's a dilemma with no easy answers, but one that we, as an organisation, are proactively addressing.

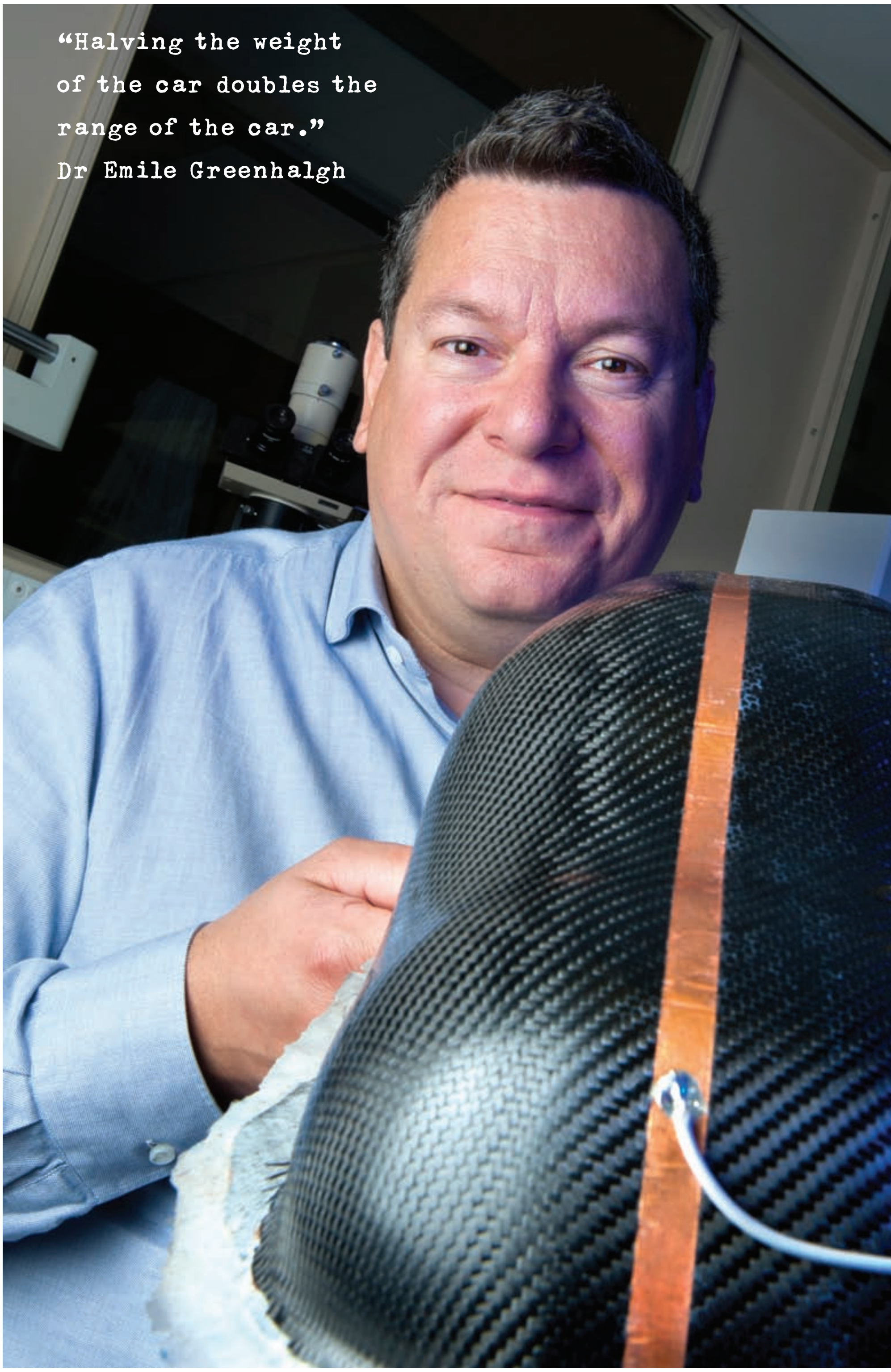
Finally, none of this would be possible without the proper support and involvement from SAE International's board of directors.

The strength of SAE's International's programmes, products and services is rooted in the intellectual property we provide. That IP helps to provide the solutions to many of the challenges faced by mobility engineering professionals.

focus@sae.org

QUEST for the SELF

A team of experts is working to integrate batteries into structural components, in a move that could not only lead to the efficiency and range of vehicles being increased, but ultimately see them powered by their own body structures. Ryan Borroff reports



An automotive body is a singularly impotent thing; a vessel which exists only for the carriage of its occupants. Its structure may be engineered to do this safely. Its form may be subsequently shaped to please the eye. Yet essentially it is a passive structure that serves no other use beyond its inherent properties.

This could change, though, because whatever cars we'll be driving in the future – petrol or diesel combustion, hybrid, electric, even hydrogen-powered – all will be required to be constructed from components that weigh less than they do now. This is particularly important for electric vehicles. One way of achieving this is by moving away from the 'one-thing-well' engineering approach and instead develop components that can fulfil multiple roles, and reduce weight and mass.

Now, the battery – a technology long derided for its innate inefficiencies – is moving centre stage. But batteries are rubbish at moving cars around. Heavy and inefficient, they have a low energy density and, if you want to power a

-PROPELLED CAR

car on electricity alone, you need a lot of them, which reduces an EV's range. Which is why, so far, electric cars don't go very far.

But even for diesel and petrol hybrids, the dream of commuting 40 miles to work and back using electricity only is still years away. Only range-extending vehicles like GM's Chevrolet Volt can travel any distance on electricity and, after 50 miles, that electricity is being generated by a gasoline engine. So it's not really running on electricity at all. Which somewhat defeats the purpose.

Integration quest

A group of nine organisations, including Imperial College London, polymer fibre composites experts Swerea SICOMP and Volvo Car Corporation are busy working to integrate batteries into structural components. In the short term, this should see the weight and mass of vehicle components (and thus potentially the vehicles themselves) reduced. This could increase the efficiency and range of such cars and – ultimately – could see them powered by their own body structures.

Volvo has been working in this area since 1995, when Per-Ivar Sellergren invented a method of integrating batteries into vehicle panels. But a recent development to use a revolutionary carbon fibre technology for energy storage has given the project a renewed impetus. Sellergren, A&V Testing Complete Vehicle, Volvo Car Corporation, explains:

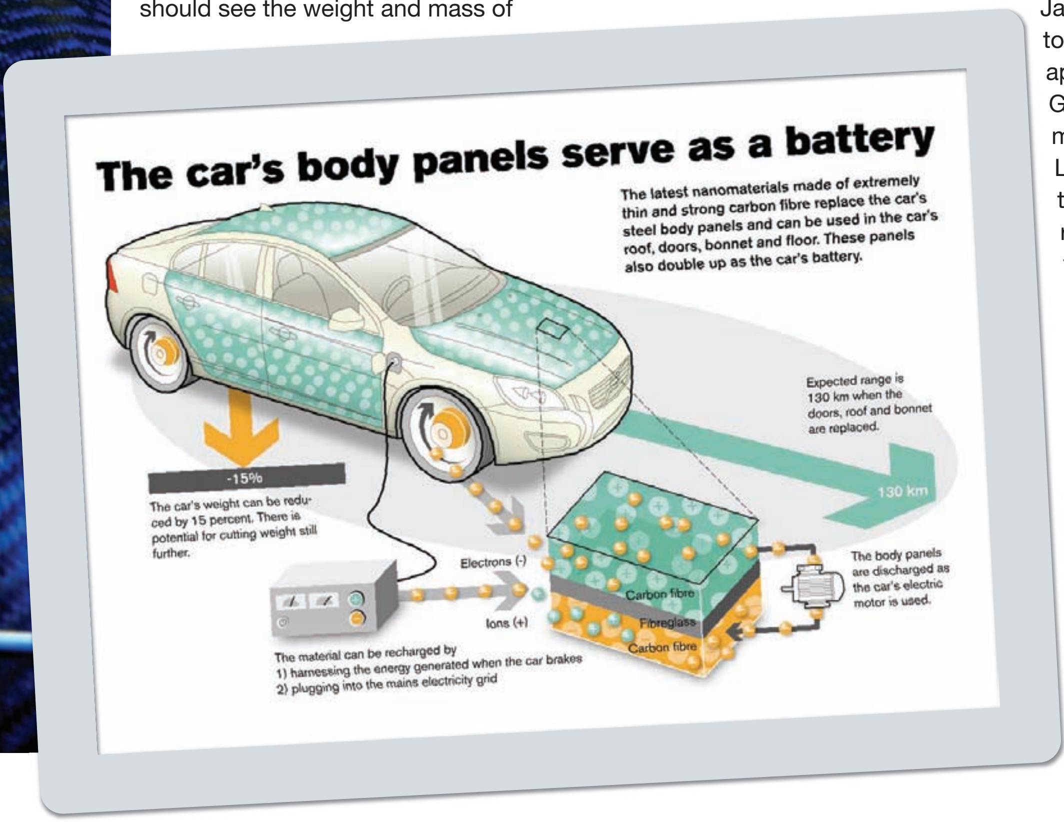
"The problem [today] for EVs is...if you add a small amount of weight [such as] a small battery, for example, you need to make a small reinforcement of the car chassis. Then this [slightly] heavier car chassis needs [slightly] heavier brakes. [Then] to run this, you need a more powerful motor and the motor needs a bigger battery and so on. But you can [reverse this downward spiral] to a positive one by making the battery very light, [so that] you need a lighter car chassis...lighter brakes and a smaller motor and [then an] even smaller battery.

Positive weight spiral

"The goal is to reduce weight and at the same time have a very good battery. More than 50% of the weight can be reduced, which is extremely good in this business. [There is also the] possibility to introduce carbon fibre [on] a larger scale. As result, we can get into the positive weight spiral that all car manufacturers have been struggling to reach for years."

The project, to develop structural battery components, was started in January 2010 and has been applied to a particular automotive application. As Dr Emile Greenhalgh, reader in composite materials, Imperial College London, explains: "The interest in the automotive field is that, by reducing the weight of the car, you can massively improve the range of the car. Halving the weight of the car doubles the range of the car. So using a material that can store the energy that drives the car and also carries the mechanical load in the car is seen as a real benefit by Volvo."

"Volume reduction is also a key driver," says Professor Leif Asp, head of research at Swerea SICOMP. "If you can save an inch in the ceiling height, which can increase space for the knees, that is



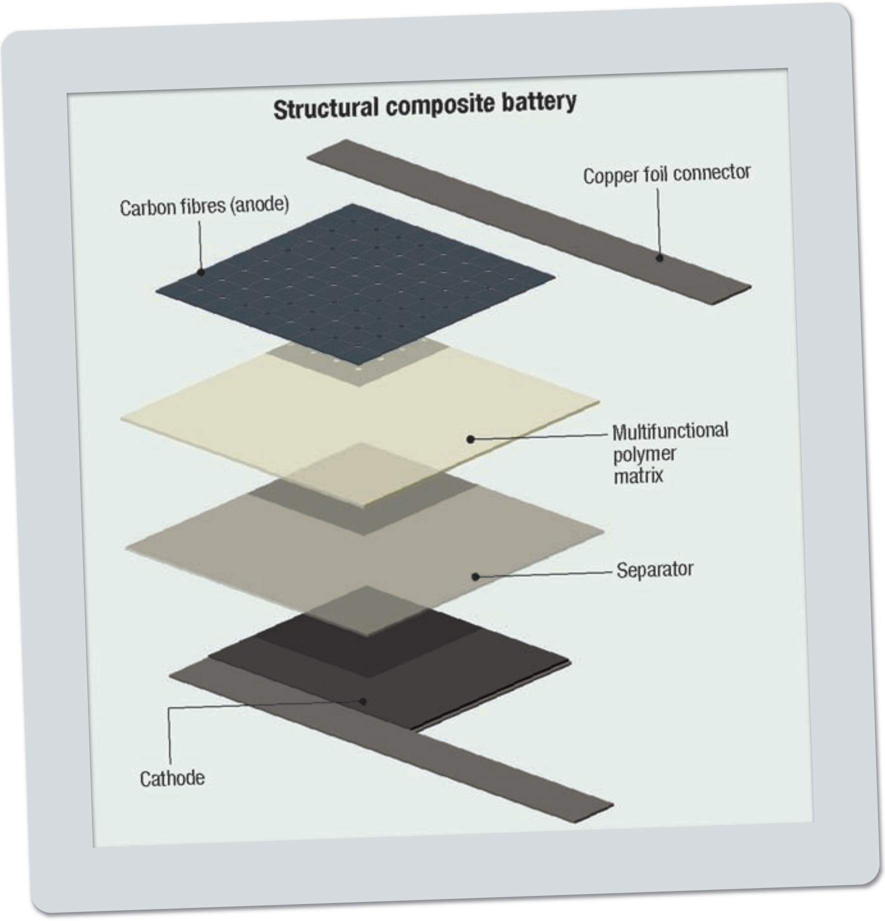
valuable, too. The value for Volvo today is reducing mass as well."

"The biggest challenge has always been to make a material that simultaneously stores electrical energy and gives good mechanical properties," says Greenhalgh. "We have now made a very big breakthrough by developing a new material that gives us both those things at the same time. It can store large amounts of electrical energy, but also get good mechanical properties with this new material – it is very rigid and very strong. So it will act like a battery or a super capacitor within any electrical device. We have done that by taking a conventional composite material, taken carbon fibres which are woven together into a cloth, put a layer of glass in between, which separates those electrodes, and infused a resin into that to make a structural material that also stores and provides electrical energy."


Per-Ivar Sellergren, inventor of the integrated battery panel

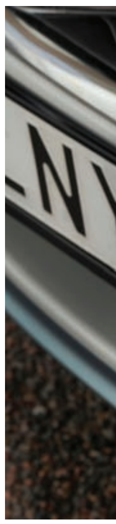
Carbon aerogels

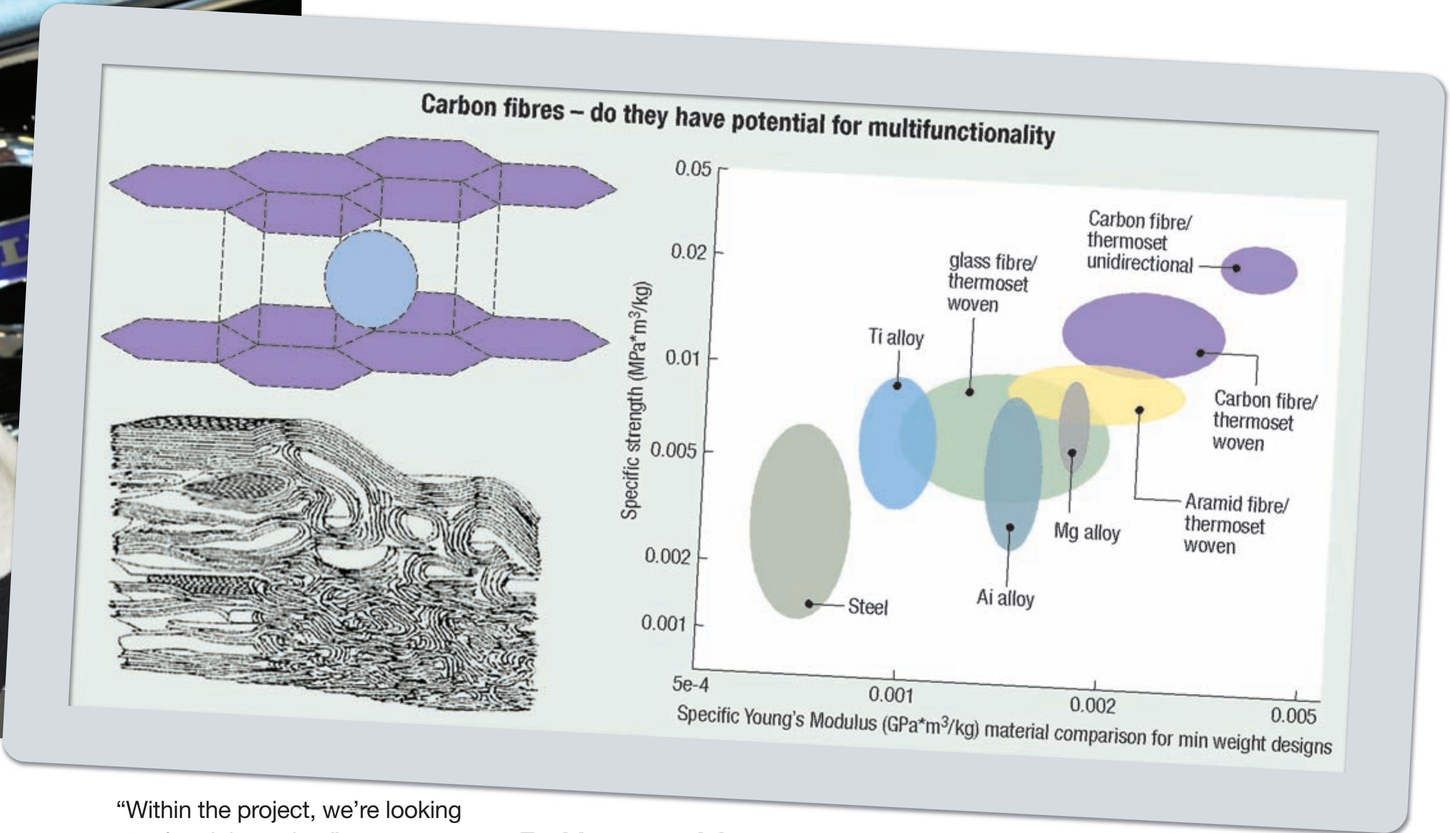
The eureka moment was in the use of carbon aerogels. Often called solid smoke, a carbon aerogel is effectively a nano foam. The team put carbon aerogels around a dry carbon fibre cloth, which increased the surface area by a factor of about 500. "But what we didn't anticipate is that, when you infuse a resin into this, this nano foam actually stiffens and improves the mechanical properties of the resin and therefore improves the mechanical properties of the composite," states Greenhalgh. "So we actually found a three-fold improvement in mechanical properties of the composite, as well as the big electrical improvement."



So far, the team has proved it is able to create highly curved structures out of the material, while still being able to store and discharge electricity. "The next level is to go from flat structures to see the effect of curvature and designing more realistic structures from this. So we are working with a high performance car company, looking at making components using our material."

In the near future, the structural power material will be used to replace existing metallic components, including the wheel well, the bonnet, the boot lid and the roof, to reduce weight and save volume. What's more, the composite material weighs less than the steel it replaces.





"Within the project, we're looking at a 15% weight saving," says Greenhalgh. "But, in the longer term, this could be larger. It could also give you more room in the car; and something else we're quite excited about is the fact that we'll be able to save on wiring in the car. So for instance...rather than having to run your GPS sat-nav off the battery – which is [located] far away from the GPS – the casing of the GPS could store the energy to power the GPS… resulting in less wiring in the car and fewer electrical faults."

Exciting potential

Thus, the potential for the technology to offer big weight savings and volume savings is massive. In the shorter team, it would mean a vehicle could require a smaller battery. But, in the future, the possibilities are even more exciting, as Sellergren explains:

"We have now made prototypes that give less than half the weight and need half the space to pack. It also gives much stiffer and durable components. [In the first instance], we will see smaller components replacing the traditional stop-start battery in electric hybrids and also replacement of the starter battery in regular cars. Then the components will grow, as bigger vehicle panels [are used] to replace the complete traction battery in an electric vehicle."

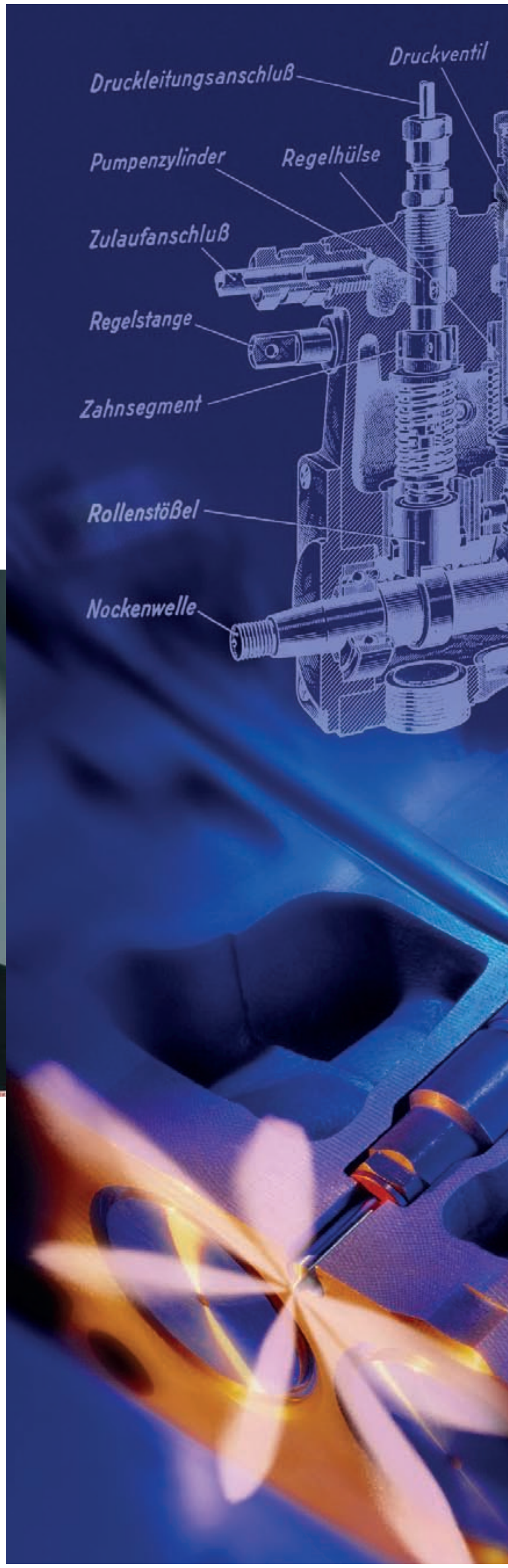
One day, theoretically, this material could replace the battery completely, with the ultimate solution being the construction of a car that uses its own body as its power source. Though it may still be 15 years away, Greenhalgh and Sellergren believe this is possible.

"It is the added value...one plus one gives three," says Sellergren. "And that's thanks to the integration of energy storage and structural attributes. And this is interesting beyond the car business; electric and hybrid airplanes – where the wings and body are made of this material – boats with decks and hulls as batteries. Smaller size components, such as cellphone shells and computer bodies, could also be perfect for this. The possibilities are huge."

Volvo leading research into an electric vehicle revolution

Flexible and intelligent

Engine management systems are becoming increasingly complex, in order to cope with a wider range of fuels, as well as tougher legislation. Chris Edwards reports



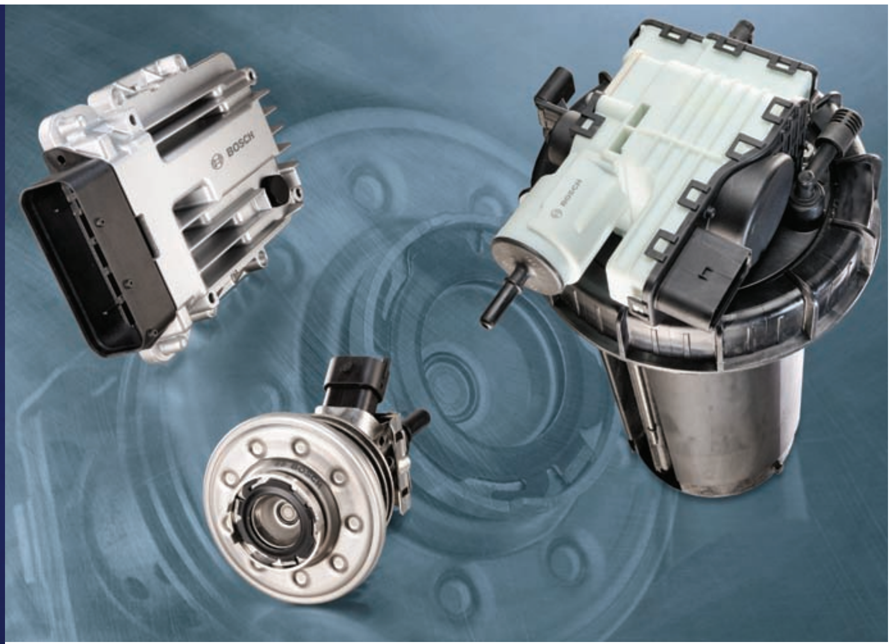
Flexibility and intelligence provide the keys to the next generation of powertrain evolution. As oil becomes harder to extract from the ground, the emphasis in automotive is likely to shift to biologically derived fuels, such as ethanol or methane, as well as electrical power from renewables.

Seasonal availability and the constraints on land to grow crops could mean large fluctuations in price and accessibility of fuel – so vehicles will need to be able to cope with a changing mixture of fuel types. This has a knock-on effect on the design, not just of engines themselves to cope with the more corrosive biofuels, but the electronic control units (ECUs) that have to work with a combination of biological, fossil and electrical energy sources.

Flexible fuelling strategies rely on the engine management software being able to detect the change in mixture between biofuels and petrol or diesel. Researchers are trying a number of alternative instruments, such as lambda sensors. One joint project between the University of Bologna and Magnetti Marelli Powertrain uses microphones to listen to the sound of the reaction

The move towards primarily electric traction will be limited, delivering perhaps three million plug-in hybrids and fully electric vehicles by 2020

Klaus Meder
President of Robert Bosch



and from that infer the proportion of ethanol injected in the chamber.

Mixed fuel strategies

Klaus Meder, president of Robert Bosch, sees a future in mixed fuel strategies. He says the move towards primarily electric traction will be limited, delivering perhaps three million plug-in hybrids and fully electric vehicles by 2020. “We think the internal combustion engine still has a strong future. We can reduce fuel consumption by 30 to 40% and, of course, this will compete with the pure electric vehicle. This 30 to 40% reduction will go along with a lot of technology that will also go into electric vehicles. Electrification won’t just affect the powertrain, but all of the electronics in the vehicle.”

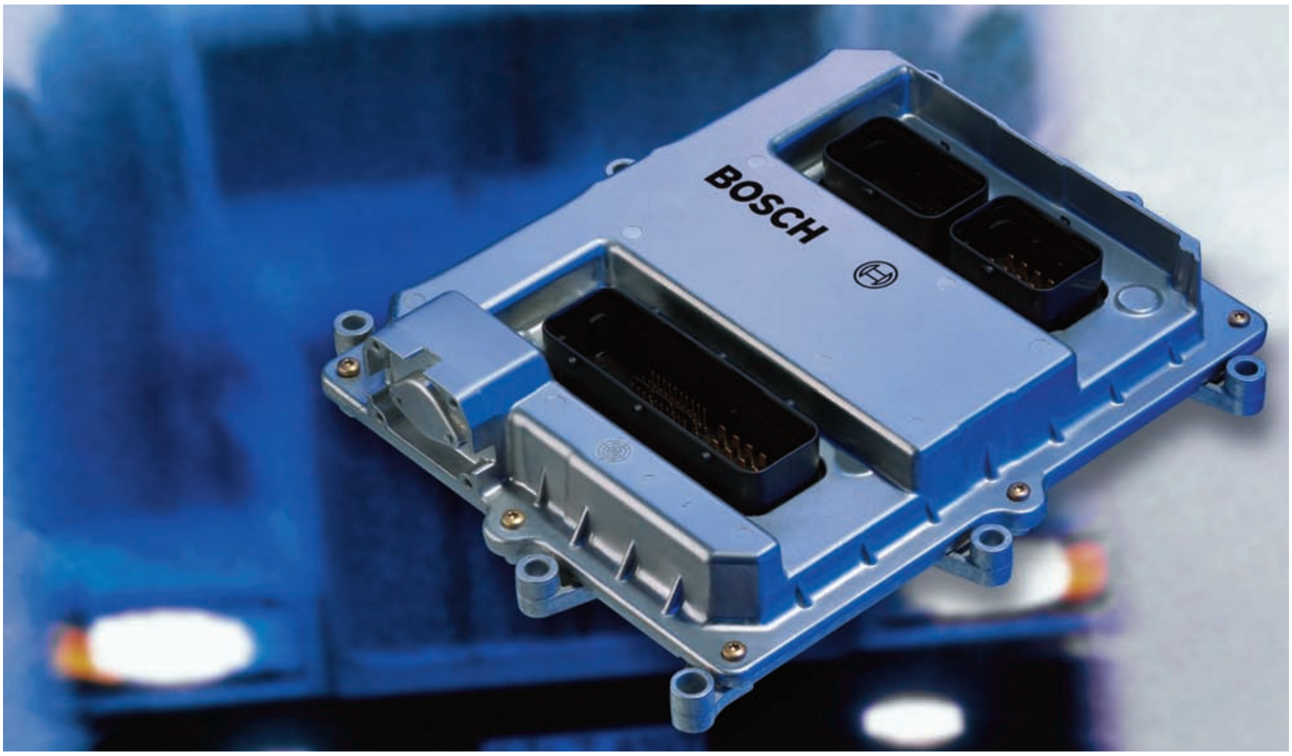
Meder’s 40% cut will not come at once, says David Price, CTO at Pi Innovo: “It’s all happening at a percentage point a time. There won’t be an end to eking out an extra half a percent through new techniques.”

So far, emissions control has focused on the ‘drive cycle’, which is typically the domain in which an engine runs at its highest efficiency. But government organisations such as the European Commission have noticed that emissions targets that focus on the drive cycle have done little to reduce pollution in urban environments, particularly for diesel vehicles.

Driving up emissions

A 2010 study, led by Helmut Eichlseder of the Technical University of Graz as part of the EU-funded Artemis programme, found that a focus on fuel consumption had helped drive up NOx emissions and that conventional tests did not capture the behaviour of stationary or slow-moving vehicles. One of the working groups within the Cars 21 programme concluded that manufacturers had successfully optimised results for tests, but not real driving conditions.

Research at the University of Cambridge indicated that sudden changes in acceleration can lead to unexpected spikes in NOx emissions. According to the university’s Professor Keith Glover, experiments performed with the help of a CO_2 gas sampler made it possible to improve the engine model and, in turn, control over the fuel and ignition cycle to dramatically reduce the NOx spikes.



The trend to downsized engines is not helping powertrain control systems' design. By moving to smaller engines, it is possible to keep them in the high efficiency region through a greater proportion of the drive cycle. But they lack power when higher performance is needed. One answer is to move to greater levels of turbocharging, but, in diesel engines, the result can be premature ignition that sometimes result in catastrophic 'mega-knocks'.

Inside view

Research establishments such as Brunel University have invested in 'glass' single-cylinder engines, using lasers to probe the chemical reactions in real time. As Professor Hua Zhao, head of mechanical engineering at the university, explains: "With the research engine, we are able to see what is happening inside the chamber. Our aim is to study mega-knock, when the pressure can go up to 300bar. We want to know how this happens and prevent it."

The response from the R&D community has been to move to model-driven strategies, some of which are based on mathematical models of the engine. Others use empirical data obtained through thousands of miles of driving, with experimental designs.

According to Glover, modelling still has some way to go. Engine control does not fit easily into the standard control paradigm, he says: "You have a huge operating range and a fairly intricate connection between decision logic and continuous dynamics, and you are switching from one mode to another."

Testing of control strategies involves the extensive use of hardware-in-the-loop systems, driven by software built using MathWorks' Simulink or LabView from National Instruments.

Direct injector control

Chris Washington, senior product manager at National Instruments, says researchers are using programmable hardware and not just microprocessors to provide faster response times. Experimental vehicles, fitted with racks of computing equipment and programmable logic, are being driven in varying environments to gauge the impact of different control strategies. "You can measure the piston with microsecond accuracy and use those measurements to initiate fuelling tasks – I/O modules allow us to control the fuel injectors directly," adds Washington. "You can switch strategies for individual cylinders and see the changes."

Outside the core control loops, models of the environment can help. The data from Global Positioning System (GPS) receivers can help the engine management systems decide where and when power is needed. For example, Mercedes-Benz is rolling out trucks with powertrain controllers that use knowledge about the road ahead to make vehicles running under cruise control more efficient. As vehicles can anticipate sudden changes in incline, the computer can avoid the rapid changes in acceleration from which traditional systems, which can only react once they notice the speed has changed, tend to suffer.

Energy optimisation

The use of GPS data can go further than simply programming cruise control algorithms to make less dramatic speed changes. They could improve the ability of diesel vehicles and hybrids to make the most of the energy they convert from fuel to electric charge. Price points out: "Batteries can only absorb so much energy. By knowing the peaks and valleys on the road, you know how much you can regenerate from braking, so the vehicle doesn't work really hard to get the battery recharged and then find a big downhill – with the result that the energy recovered there all has to go off in heat."

Knowledge about the route programmed into the GPS could be used to avoid wasting energy on cleaning the filters that diesel engines need. "When regenerating a partially blocked filter, if you know you are going to go on a motorway, no need to do extras in the town section. As people use them more for setting routes, you know ahead which route you are going to go along," Price adds.

"We see these use-cases coming up," says Drue Freeman, vice president of NXP Semiconductor's automotive division, who perceives greater integration between the powertrain and not just other parts of the vehicle's communication network, but those of other cars and the highways' infrastructure. Information about traffic and road conditions reported by other vehicles will feed into the increasingly advanced models that control the powertrain.

Playing to a different tune

The science of induction tuning has embraced everything from the mad and bad to suitably plausible at times. Is the intake sound generator about to change all that? Andrew English reports

Those long enough in the tooth will recall the old shots of Can-Am race V8s festooned with what appeared to be a series of top hats for cats.

Tuning the length and size of the inlet and exhaust tracts to exploit the extractive power and resonance of the air flow to improve the breathing has been known about even before Freddie Dixon set about Riley engines at Brooklands in the Thirties. Sometimes that tuning gave an unmistakable quality to the (noise) sound: the flat bark of a Cosworth Ford BDA or the guttural rasp of a Porsche flat six.

Keeping the passion

And sometimes it didn't, and the intake roar was simply annoying and intrusive. Yet removing it could also strip character from premium models. Seems we got so good at quietening the engine, we lost all the passion in the process. These days, to put back some of the quality, intake sound generator, or Symposer, is the science du jour.

Graham Franks, senior consultant with Sound and Vibration Technology, explains. "The sound generator is simply a form of pipework connected to the intake duct that moves the sound source closer to the car's occupants," he says.

His colleague Richard Johnson further explains. "Intake roar is what is left after the performance and the economy guys have been in, but it's often very raw and we have little control over it. In the past, certain car companies, such as Porsche, simply piped that sound up to the bulkhead. These days, they and most of the industry use intake sound generators."

"Everyone's getting really clever at maintaining a sporty engine note," adds Franks, "but not so clever at controlling the error states of low frequency noise and booming."

Music to the ears

So what's the difference between an imposer and a Symposer? "A Symposer is the very specific induction sound generator, made by Mann and Hummel," says Franks, describing two main sorts of sound generator, dividing applications between naturally aspirated and forced-induction engines. On the former, the generator can be connected to any point of the induction system to give a broad base of harmonisation.

"It's like tuning a woodwind instrument," he says. "It's an over-simplification, but we're looking at frequencies between about 150 to 1,000Hz that sound nice." The length and diameter of pipe, where it is placed, how it runs and how it attaches are all crude means of tuning the sound. Tapping the manifold downstream of the air filter means that sealing of the device is required with a flexible membrane.

Forced induction engines, however, have a problem, as additional pressures overstress such membranes and they also sound awful, if you tap the noise downstream of the turbo or supercharger.

Knowing the drill

"Just like a dentist's drill," says Matthias Alex, an NVH supervisor with Mann and Hummel. Alex jointly invented the Symposer and doesn't seem too put out that people wrongly attribute the name. "It's actually pretty flattering that people call all sound generators Symposers," he says.

The Symposer's first automotive application was on the 2005 Ford Focus ST, with its sonorous five-cylinder Volvo engine. "Drive-by noise limits mean you cannot simply make the exhaust louder," he says, explaining that the Symposer's four chambers and plastic paddle allow the engine's sound to be transmitted back to the cabin, with no effect on performance and economy tuning, and that it is eminently tunable by changing the size of the chambers and the flexibility of the paddle.

On the current four-cylinder Focus ST, the Symposer is placed directly onto the inlet manifold immediately behind the throttle body, which involved the use of an electric valve to maintain the noise, even when the throttle was closed.

Making the right noises

What all of the noise engineers we spoke to concur on is the need for practical experience in the field to make best use of sound generation. Computer modelling is improving, but, as Franks points out, it is best at predicting the effect of changes, rather than absolute values.

"We offer an holistic approach," he says. "The challenge is to combine the best of computer modelling with real life measurements to provide, and then achieve, vehicle level sound quality targets. We use a change modelling approach, combined with immersive vehicle simulator assessments, to ensure that the sound is what the customer wants, before committing to tooling."

Simon Roberts is a consulting engineer with the Institute of Sound and Vibration Research at Southampton University. He agrees that sound engineering can be a bit of a black art. "Noise issues are not quite inherently unpredictable, but some are," he says. He points out that, with ever-decreasing legislation on drive-by noise, a lot of frequencies that were drowned out are now having to be addressed.

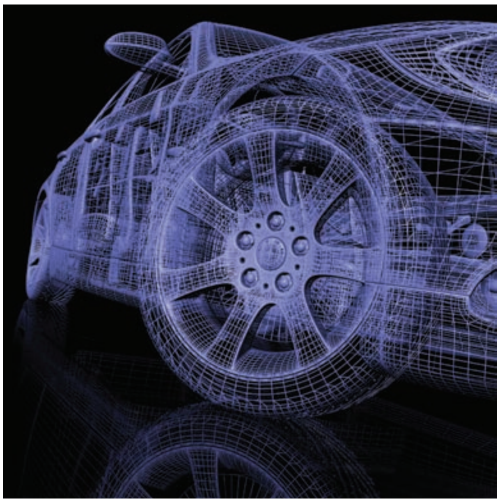
Active noise systems

Like Franks, Roberts says active sound generation is the coming thing and might even replace the analogue sound inducer. "The hardware is getting feasible and that's whether you chose to control noise through the hi-fi or with inertial exciters," he comments. "I would be surprised if most vehicles aren't running some sort of active noise systems within five years. That's not just for sound quality, but also to save weight by removing low-frequency sound with electronics, rather than heavy sound deadening."

It is here, in the control of active noise, that the ISVR is amongst the foremost research establishments in the world. "We've enormous experience with engines and whole vehicles," says Roberts. "In that field, we're world leading."

So, will active sound/anti-noise mark the end for Alex's mechanical Symposer? He doesn't think so. "Electronics have the potential to be faster," he concurs, "but, if you talk to the engineers, they are concerned that active sound generation could end up as a 'fake' sound," he adds. "We still need the engine as a sound driver."

Besides, with its electric valves, the latest generation of Symposer is at least a hybrid or semi-active device and Alex sees no reason why it hasn't a long future. Drivers still use their ears to monitor the engine's load condition and speed to help them, and that isn't going to change. "We need to listen to our engines," he cautions.



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In its third year, the virtual summit is the largest online conference developed specifically for those involved in the design and/or implementation of drivetrain technologies including axles, transmissions, and torque control devices for automotive, commercial, and off-highway vehicles.

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FOAM

Lou Reade talks to Bert Suffis, application sales manager of JSP

"Arpro is isotropic. We can design and produce complex 3D geometries, but still be confident that performance will be as we expect."

ADVANTAGE

New entrants to any market are at a huge disadvantage: in order to chip away at their established rivals, they must invest in the latest technologies, if they are to compete. Technologies that are usually very expensive.

However, some modern materials and techniques may help to overcome this crucial stumbling block. Materials company JSP, for instance, believes that its Arpro material – a closed-cell polypropylene (PP) foam – is one of these. It has already helped to deliver substantial weight savings to a range of 'conventional' cars.

An early application of the technology was in seat cushions, when JSP collaborated with Porsche to develop an 'anti-submarining' ram for its Cayenne model. "We saved 10kg in seat structures by replacing thick sheet metal with Arpro," says Bert Suffis, the company's application sales manager.

Knowing all the angles

Arpro absorbs energy from a hit and has a 'resilience', allowing it to function a second or third time. Injection moulded structures usually perform well in one direction, but, if the impact is slightly offset, then performance will be different. But Arpro works at all angles, he insists.

"Arpro is isotropic. We can design and produce complex 3D geometries, but still be confident that performance will be as we expect."

Now, says Suffis, the material is moving into more unconventional applications – because what could be more unconventional than making a car chassis from plastics?

UK-based Inrekor has constructed a very light chassis – comprising a relatively thick Arpro core, joined to two thin outer sheets of steel or aluminium – that is around 30% lighter than a traditional chassis. "Inrekor is very scalable; there's no need for huge upfront investment in stamping and metal forming. That's usually a very large hurdle for a small company."

This structure has been incorporated into the QBeak, a new generation of electric vehicle developed by Danish car manufacturer EcoMove.

Little investment

A critical element here is tooling. Chassis panels traditionally require large – and very expensive – stamping machines, in order to produce sheets of the correct shape. Inrekor chassis panels require very little investment, explains Suffis.

Arpro parts themselves, which have been used in seat cushions, bumpers and many other areas of the car, also require relatively inexpensive tooling – aluminium-based tools, rather than the hardened steel needed for injection moulding tools. This is because the parts are foamed (so require lower pressure) and are generally made in lower volumes – using steam chest moulding, rather than injection moulding.

The Inrekor-based chassis will be crucial in the development of the emerging generation of small electric vehicles, says Suffis. "The early adopters will be the new car makers, but I'm convinced that existing vehicles might begin to use Inrekor in their next-generation sub systems."

Fuel protection

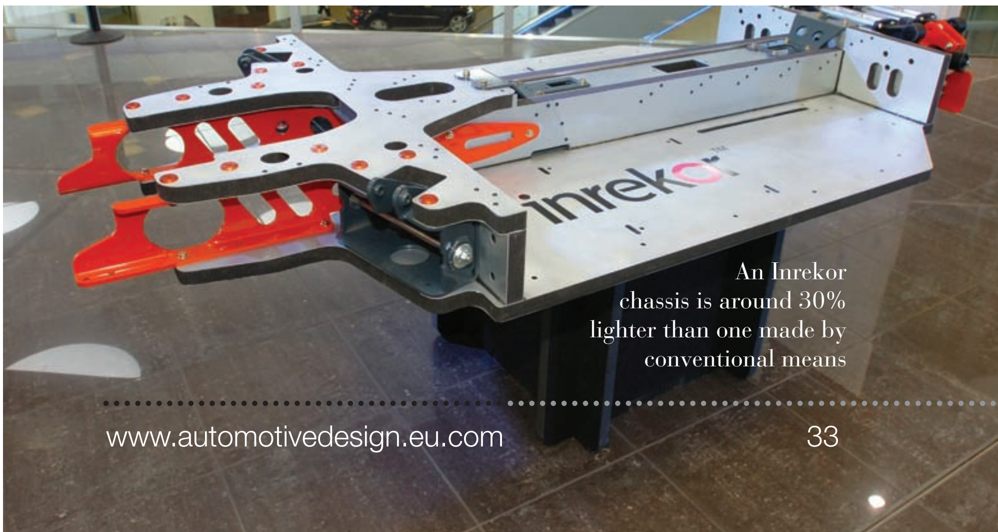
Another recent use of Inrekor was to protect the fuel bladder in an Aston Martin racing car. Because Inrekor parts can be made flexibly, and relatively cheaply, it allowed the designers to tailor the product to the needs of the car. "The key advantage in this application – other than the weight saving – was the absolute lack of investment needed."

This kind of part is usually made from composites, which would be far more expensive and time consuming. At the same time, a composite system would need to be built and installed within the roll cage. The Inrekor part can be created from a number of separate components and retrofitted 'piece by piece' – after the roll cage has been welded into place.

"It's like keyhole surgery," says Suffis. "It means the fuel bladder can be made smaller – allowing it to be tuned for certain races."

Arpro Recycled

With Arpro made from a single material, it is easily recyclable. But JSP has launched a variant, called Arpro Recycled. This contains 15% recovered PP – but it is guaranteed to have the same mechanical performance as its 100% 'virgin' grade. "One manufacturer is already using it in a rear bumper," Suffis reveals.



An Inrekor chassis is around 30% lighter than one made by conventional means

Thomas Broberg, senior technical adviser safety Volvo

Train of thought

"As the Safe Road Trains for the Environment (SARTRE) project draws to a close, we're looking at how we can apply some of the lessons we've learned into future research here at Volvo, especially with regard to simplified, low-speed situations. Maybe we won't relieve the driver of all their duties, making them still responsible for their vehicle, but develop semi-autonomous modes.

"We're looking into how we can apply some of the concept in certain traffic conditions; for instance, in slowly-moving traffic, in order to facilitate smoother traffic flow. But it could also free up the driver to do something better as well; some drivers do that already, when using their mobile phone, and that takes their attention away from traffic. You can ban that, but maybe it's perhaps better to help facilitate that, because people want to stay connected. There's a need for that. SARTRE took that to its limit; maybe we can take it to a lower level initially.

"SARTRE was bit like a 'Kinder Egg' with three surprises: safety, economy and congestion. The ambition was to have a 10-20% reduction in fuel consumption, and for safety, zero accidents. Congestion was hard to target, but, if we could get an extra two to three cars in the space usually occupied by seven or eight, that would be beneficial.

"A lot of these aspects need to be further developed. What we've done with this research project is show what we're capable of doing with today's technology, in terms of sensing, vehicle-to-vehicle communications. This will raise all these other questions: who is responsible, how do you address that, how do you switch in and out of the loop? What's the definition of a professional driver? Those are all parts of the project that need to be further evaluated before it goes public on the road.

> "We're looking into how we can apply some of the concept in certain traffic conditions; for instance, in slowly-moving traffic, in order to facilitate smoother traffic flow."

"And factors such as the Vienna Convention have to be considered. But what is good is that you're stretching technology and you also learn a lot of other aspects: what would be the optimum distance between the vehicles? Not necessarily the closest, from a technological or fuel economy point of view, because you also have to account for the drivers' wishes – if you're too close and can't look forward, how would you feel? We've seen issues with water spray and the drag effect; we've seen a zone of turbulence behind a vehicle that can affect following traffic. All that needs to be investigated.

"When you try something out, you get to know more of the things you hadn't originally thought of."