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Volkswagen, now the world’s largest automaker, will not develop gasoline engines smaller than its current 1.0 litre three-cylinder, nor diesels below 1.6 litres. Brand head Herbert Diess cited the advent of Real Driving emissions (RDe) standards for the move, noting that the disparity between RDe and current lab tests was greatest in Germany, where just 9-10 kw was required for the test but some 100 kw to drive at 200 km/h on the autobahn. This year’s new Polo range would include a diesel option, Diess said, but its replacement probably would not.

Toyota is claiming improved performance, consumption and emissions for its new 1.5 litre gasoline engine in the Yaris, which replaces a smaller 1.33 litre unit. Ford’s new Fiesta uses a powerful 200 hp iteration of the EcoBoost 1.5 litre three for its sports ST version, while premium models are seeing smaller combustion engines linked with 48-volt hybridization – evidence, perhaps, that downsizing works best when a surplus of power is available.
Geneva’s wilder side

Extremes of speed and power have long been associated with the Geneva motor show, and 2017, with the debut of all-new models from Ferrari and McLaren, did not disappoint.

Ferrari’s new 6.5 litre V12, mounted up front in the 812 Superfast, is the most powerful production engine in the marque’s history, while the McLaren 720S (above) breaks rather different records – it weighs just 1285 kg and with a 4.0 litre twin-turbo V8 (built by Ricardo) it makes 720 hp for a top speed of 241 km/h. Other notable points include the absence of side air scoops – the cooling function is handled by the door design – and an instrument cluster that changes in size according to the driving mode.

Lamborghini’s Huracán Performante, now with active aerodynamics, offers 631 hp, somewhat behind the new – and lighter – €2 million Pagani Huayra roadster at 745 hp. Completing the exotic pack were oriental optimists Vanda Dendrobium with a Williams-engineered electric drivetrain and deconstructed styling along the lines of KTM’s X-Bow, as well as the Techrules GT96 with turbine-recharged battery power, and a pair of Pininfarina-styled hopefuls in the shape of Emerson Fittipaldi’s EF7 Gran Turismo and Chinese brand Hybrid Kinetic’s PF H600 luxury sedan.

On a much more accessible level, the Renault Group’s new Alpine A110 blends all-aluminium construction with a small engine and clever aerodynamics to promise an exhilarating everyday drive – at just €58,500 for the plush launch edition.

Buses to electrify fastest

One third of all new transit buses will be electric by 2020, and by 2030 the figure will be 100 percent. Those are the predictions of Ryan Popple, CEO of Proterra – a California-based e-bus maker which is soon to open its second manufacturing facility. In Europe, meanwhile, business continues to grow for e-bus makers such as Volvo. The Swedish company has sold over 100 of its 7900 series hybrid and pure electric buses this year, including eight to the English town of Harrogate.

Hydrogen edges closer

The prospect of hydrogen as a road fuel has come a small step closer – at least in California. Shell and Toyota are under consideration by the state’s Energy Commission for a $16.3 m award to build a seven-station hydrogen fuelling infrastructure, and it is reported that California Air Resources Board chair Mary Nichols is hoping to achieve 100 percent zero emissions in the state’s light vehicle fleet, though no timetable was given.

GM and Honda are to co-operate on the manufacture of fuel cell systems with in a Michigan-based joint venture, while in January the US Department of Energy awarded a prize to the SimpleFuel consortium for its home hydrogen fuelling system. The device enables hydrogen to be generated at home from a domestic gas supply, giving owners independence from commercial fuelling stations.

I N BRIEF

Highlighting the latest thinking in automotive engineering and technology worldwide

**Formula E powertrain**

Two concept models at the Geneva show made use of electric powertrains drawn from the current Formula E race series. Singapore’s Vanda uses this driveline as a temporary measure pending the arrival of its definitive powertrain, while at the opposite end of the scale Renault’s hotshot ZOE e-sport has twin e-motors totalling 460 hp for spectacular performance and a 0-100 km/h time of just 3.2 seconds.

**Korean group plugs PHEVs**

Hyundai Motor Group launched no fewer than three new plug-in hybrid models at the Geneva show in March: the Kia Optima and Niro as well as the Hyundai Ioniq PHEV, also showcased as an autonomous concept. Further bolstering the Korean group’s green credentials was a stylish fuel cell powered concept with a fourth-generation system offering a range of 800 km.

**PSA gets real on consumption**

Coinciding with its takeover of Opel-Vauxhall, French automaker PSA Group has launched the next stage of its open-book policy on real-world emissions. Now, drivers of Peugeot, Citroën and DS models can log on to company websites and access online calculators that predict each model’s consumption depending on driving style, loading and road conditions.

**And the EV winner is…**

The world’s leading manufacturer of plug-in vehicles is not, as might be expected, Nissan, Tesla or Renault. Instead, China’s BYD is the top producer, boosted by strong sales in its home market as well as production of electric taxis for many of the world’s cities, including Brussels, London and Rotterdam.

**In-car payment launched**

Jaguar and Shell have joined forces to develop the world’s first app allowing drivers to pay for their fuel through the vehicle’s touchscreen. The system means drivers no longer have to wait in lengthy queues at filling stations, and receipts with location data are automatically sent to the user’s account. Launched initially at selected UK stations, the scheme may later be extended to other countries and services.

**Camaro closes in on 200 mph**

The latest Chevrolet Camaro, complete with 650 hp supercharged V8 and 10-speed automatic transmission, has a rated maximum speed of 310 km/h, verified in testing at Germany’s Papenburg GmbH proving ground. Peak speeds during the two-way testing to counter the effects of wind direction were 292.3 and 193.3 mph. The 2017 ZL1 is priced at around $65,000 including taxes.

**Green rail travel**

Take a train in the Netherlands and it is guaranteed to be clean. Since the beginning of 2017 all power for the Dutch railway system comes from renewable sources, with 1.2 billion kWh of wind energy provided by Eneco per year. The network hit its target of 100 percent renewable power one year early after the 75 percent mark was reached last year.

**GM reveals new electric car**

General Motors is to join forces with Honda to develop a new electric vehicle. The two companies plan to release a platform and an electric drivetrain for a family of vehicles on the US market. The announcement was made during the North American International Auto Show in Detroit, Michigan.
The net tightens around diesel

Against a background of diesel car restrictions in a growing number of European cities and consumer anger over real-world fuel consumption discrepancies, the European Parliament committee investigating the diesel crisis has called for a new agency to oversee road transport in the EU. The committee’s recommendations are not legally binding, but centre on a revision of national testing procedures and responsibilities.

Calculations by Brussels-based NGO Transport & Environment show that new cars consume on average 42 percent more fuel on the road than advertised in sales brochures. In 2006 the discrepancy was just 14 percent. The real-world improvement in consumption since 2008 is just 14.6 g/km CO₂, says T&E, and since 2012 there has been no improvement in efficiency. Some models burned as much as 56 percent more fuel than advertised in marketing materials, claimed T&E clean vehicles director Greg Archer.

In 2016 European Consumer Organisation BEUC concluded that electric vehicles will drop in price substantially and that, by 2024, the average four-year cost of running an electric vehicle should match, if not be lower than, a gasoline car. In December a report by investment bank UBS predicted that diesel would “almost disappear” from the global car market by 2025 as 48-volt gasoline hybrids become more financially attractive than diesels constrained by costly exhaust aftertreatment systems.

In the US the American Council for an Energy-Efficient Economy (ACEEE) has named the Hyundai Ioniq Electric as the new vehicle with the lowest overall environmental impact. It narrowly outpointed the BMW i3, Fiat 500e and Toyota Prius Eco. All the vehicles in the ACEEE top 12 featured some form of electrification. The new Chevrolet Bolt EV finished in sixth place, just behind the Nissan Leaf.

Volkswagen takes top slot

It was a close-run contest, but Volkswagen finally edged just past Toyota to become the world’s biggest automaker: its multiple brands sold a total of 10.3 million vehicles in 2016, compared with the Toyota group’s total of 10.2.

Long-time market leader GM, which lost its crown to Toyota in 2008, just held on to third spot, a hairsbreadth ahead of a fast-accelerating Renault-Nissan Alliance boosted by its acquisition of Mitsubishi Motors.

In the premium sector Daimler is catching up fast and, rising 11 percent to 2.08 million units in 2016, is closing in on leader BMW’s 2.368 million total, 360,000 of which were Minis.

More battery chemistries vie for attention

Electric-car battery costs have fallen every year since 2015, according to a report from the Frankfurt School of Finance and Management, with 2014 to 2015 alone accounting for a drop of 35 percent.

While almost all current systems are of the lithium-ion type, a rush of new chemistries is vying for the attention of automakers. Samsung SDI’s new cell is claimed to offer not only lower weight but also much faster recharging at some 20 minutes to full; however, it may not be production ready until after 2021.

Swatch subsidiary Belenos Clean Power is investing heavily in its vanadium-based chemistry for automotive batteries and is linking up with China’s Geely – which controls Volvo and London Taxi International – to test the new technology on the road.

Among the advantages claimed for vanadium are a 30 percent improvement in range, twice the speed of charging and a doubling of battery longevity.

At present more suited to domestic and industrial applications is a new flow battery developed by Harvard’s School of Engineering and Applied Science. Thanks to re-engineered water-soluble molecules in its positive and negative electrolyte tanks, it avoids the need for regular decontamination shutdowns and suffers less than a one percent fallow in capacity for every 1,000 cycles.
New Volvo steers out of trouble

The Volvo XC60 debuting at the Geneva motor show introduces three new safety systems, all of which rely on automated intervention in the steering to prevent or mitigate a potential collision.

The familiar City Safety system has been upgraded to intervene when the existing automated braking sequence is by itself not sufficient to allow the car to avoid a collision. This obstacle avoidance function operates between 50 and 100 km/h.

The new Oncoming Lane Mitigation system intervenes, again in the steering, if the driver veers into the path of oncoming traffic. Operative between 60 and 140 km/h, it automatically steers the vehicle back to safety in its own lane.

The Blindspot Information System, BLIS, is now complemented by steering intervention as well as audible and visual warnings, alerting the driver should he or she pull out into the path of a car close behind; again, the vehicle is safely steered out of danger.

Mixed messages on renewables

With US greenhouse gas emissions at their lowest for 25 years and the country’s households enjoying their cheapest energy for half a century, Lazard’s Levelized Cost of Electricity Analysis reports that renewables now provide the cheapest unsubsidized electricity in North America.

Natural gas [now 34 percent] has overtaken coal as the nation’s main source of energy; renewables now account for 15 percent and in 2016 more solar capacity was added than either natural gas or wind. Nevertheless, according to Bloomberg New Energy Finance, global investment in green power has fallen 18 percent and in 2016 more solar capacity was added than either natural gas or wind. Nevertheless, according to Bloomberg New Energy Finance, global investment in green power has fallen 18 percent since 2015 and the sector is preparing itself for major changes following the change of administration in Washington.

Initiatives continue to thrive in Europe, with UK offshore wind power costs falling more sharply than expected and soon drawing level with gas and coal. France has launched a suite of measures, including green or solar roofs on commercial premises, and the roll-out of solar generating roads.
Nissan engineers gasoline’s next big step

Around a century has passed since Sir Harry Ricardo predicted the performance advantages of Variable Compression Ratio. The intervening decades have been littered with attempts, mainly unsuccessful, to solve this particular engineering conundrum. Now, it seems, the code has been cracked, and the first VCR engines will appear in 2018 powering an Infiniti SUV. Ian Adcock spoke to Nissan’s chief powertrain engineer, Shinichi Kiga, to get the story behind this significant engineering achievement.

When did you first start work on variable compression ratio engines?

We have been working on this technology for over 20 years and in that time we have filed more than 400 patents for the engine in addition to the earliest patent for VCR, which dates back to 1932. The big breakthrough came in 1998 when we mastered the multi-link technology – that was the key enabler to achieving variable compression ratio. It moved into advanced engineering in 2005 and then the project phase started in 2010-11. Over the years more than 100 prototype engines have been developed and tested, spending more than 30,000 hours on test beds. This equates to more than three million miles of on-road testing. We’re now in the final phase of real-world testing before the engine is launched in the Infiniti QX50 premium crossover next year.

What was the impetus driving this development?

Achieving good fuel economy can be quite expensive: electrification is one solution but that can be costly. VCR is a more conventional solution and is much cheaper when compared to electrification such as a plug-in hybrid or 48 volts. It also works out cheaper than a diesel when built in the same numbers although, admittedly, the VCR’s fuel consumption isn’t quite equal to a diesel’s. However, it means we can achieve good fuel efficiency with a high compression ratio and still get the equivalent performance of a V6 engine, but with a four-cylinder engine for improved fuel consumption, less weight and at a lower price.

Where was the development carried out?

Principally in Japan, but Infiniti’s partnership with the Renault Sport Formula 1 team proved instrumental in accelerating prototype testing, especially in the latter stages of development. Because of the advanced design of the multi-link system the engine features around three times as many bearings as a conventional four-stroke; during development a small bearing vibration was identified at high engine speeds under certain conditions. Our F1 colleagues helped identify and isolate the problem by using their expertise in dynamic motion analysis at engine speeds up to 20,000 rpm – far higher than in
Is the engine exclusive to Infiniti?
No, although it is being launched in the new QX50 crossover next year, the technology will be available to all brands within the Renault Nissan Alliance. This is not a ‘one-shot’ technology for a single model, but a new engine family: it enhances the future prospects of the gasoline engine. We opted for two litres to replace the 3.5-litre V6, but it’s possible to develop other engines as well – although cost becomes a crucial factor with smaller-capacity units. Having said that, we believe this solution is better value for money than some of the other variable compression ratio technologies that are currently under development and, most importantly in our view, it is truly variable from 8:1 to 14:1 rather than being a simple two-stage system.

How does it compare to the engine it is replacing?
On all fronts it is equal to, and in many aspects better, than the V6. We are targeting 200 kW and 390 Nm which, for a two-litre, is impressive, especially when there’s a 27 percent improvement in fuel efficiency as well as a dramatic reduction in NOx and particulate emissions compared to a diesel. Despite the complexity of the variable compression linkages, the engine is 25 kg lighter than the V6 thanks to its linerless aluminium block and cylinder head, whilst using high carbon steel alloys for the linkages has kept any weight increases down to a minimum.

How have other systems on the engine changed?
The exhaust manifold and cylinder head are amalgamated into one assembly, improving packaging and enabling a more intelligent integration with the turbocharger and catalytic converter – whilst also saving weight. We believe the VCR system helps reduce vibrations by a third, eliminating the need for a balancer shaft as the VCR system allows us to avoid secondary harmonic vibrations, and the engine moves seamlessly between compression ratios, sensing the car’s driving condition and driver inputs, and instantly selecting the most suitable compression ratio. Under hard acceleration or at heavier engine loads – for instance, when overtaking another vehicle or driving uphill – the engine shifts to a lower compression ratio. This results in higher performance, offering a compression ratio comparable to that of powerful turbocharged 2.0-litre four-cylinder engines.

At steady motorway speeds, under slowing driving conditions, at idle, and at low speeds in stop-start traffic, the engine defaults to a higher compression ratio to maximise efficiency.

How Nissan’s Infiniti solved the VCR conundrum

Key to the Infiniti engine is the electrically-powered Harmonic Drive reduction gear that drives a connecting control arm. The Harmonic Drive rotates according to the compression ratio required at any given moment: this then rotates the control shaft at the base of the engine, in turn moving the multi-link mechanism. Changing the angle of the multi-link alters the geometry of the tops of pistons, thus varying the compression ratio. An eccentric control shaft varies the piston stroke position for all four cylinders at the same time.

This multi-link system means the pistons’ connecting rods are almost vertical during the combustion cycle, rather than moving wider laterally as in a traditional crankshaft rotation.

Comparison of VC-Turbo technology in high and low compression ratios

Understanding VC-Turbo technology
1. When a change in compression ratio is needed, the Harmonic Drive turns and moves the actuator arm
2. The actuator arm rotates the control shaft
3. As the control shaft rotates, it acts upon the lower-link, which changes the angle of the multi-link
4. The multi-link adjusts the height the piston can reach within the cylinder, thus changing the compression ratio
delivering a really smooth running and quiet engine. In the VC-Turbo, engine vibration noise is reduced from a benchmark average of approximately 30 dB to just 10 dB.

Apart from gains in fuel efficiency, what other benefits does VCR technology deliver?

We achieved a 44 percent reduction in cylinder friction by specifying plasma-jet coated bores that are hardened and honed to deliver a low friction surface, eliminating the need for cylinder liners; as a result of reduced side forces there’s lower friction between the rings and bore. Admittedly, there’s an increase in pressure on some of the bearings, but no more than you’d find in a similar sized diesel engine, so nothing that isn’t containable.

What about fuelling strategy? That must have been a challenge considering the compression ratio spread from 8:1 to 14:1?

The VC-Turbo engine employs a combination of both multi-point injection (MPI) and direct injection (DIG), further improving the engine’s ability to balance efficiency and power in all driving conditions. The DIG system improves combustion efficiency and performance due to the heat-absorbing effect of fuel vaporization – which aids cylinder cooling – and allows the engine to avoid ‘knocking’ at higher compression ratios. MPI allows for earlier mixing of air and fuel to increase engine efficiency at low loads. Like the compression ratio, the engine can switch instantly between DIG or MPI at regular engine speeds, while both sets of injectors work in conjunction under a combination of high engine speeds and load. The engine can also switch seamlessly between Atkinson and regular combustion cycles; the Atkinson cycle is activated under higher compression ratios, where the piston stroke is longer. The modern Atkinson cycle – employed in many advanced hybrid engines – allows the intake valves to be open for a short time as the compression stroke starts. Then, as the compression ratio lowers, to enable greater engine performance, the engine reverts to a regular combustion cycle resulting in improved performance.

Shinichi Kiga is Chief Powertrain Engineer of Nissan’s Gasoline Engine Project Group

Saab: Variable Compression Ratio came close to production

Seventeen years ago the now defunct car-maker Saab unveiled its own take on a variable compression ratio engine at the 2000 motor show. Questioned by Ian Adcock for European Automotive Design, Saab’s then head of powertrain, Kjell ac Bergström, declared that the “engine has the potential to revolutionize the internal combustion engine and extend its life well beyond the introduction of rivals like fuel cells.”

The Saab Variable Compression (SVC) engine comprised two main elements: the upper section, or monohed, consisting of the cylinder head and integrated cylinders, with the second part formed by the engine block, crankshaft, connecting rods and pistons joined to the monohed with a rubberised bellows. Although the SVC was a unique Saab engine, Bergström was keen to emphasise that future variable compression engines could utilize existing cylinder heads, pistons and cylinder liners to help minimise development and manufacturing costs.

Saab’s VCR worked by decreasing and increasing the cylinder capacity by changing the combustion chamber’s position relative to the block. This was achieved by a patented hydraulic actuator which moved the monohed through four degrees to vary the compression ratio between 8:1 and 14:1. Bergström stressed that these parameters could be varied according to individual demands, with an upper limit of 20:1.

The challenge, concluded Bergström, was to develop reliable and quiet bearings for the tilting mechanism. Unlike rotating bearings, these slide back and forth, so the lubrication and clearances were critical if slap and unwanted noise were to be prevented.

The SVC utilised a mechanically-driven intercooled supercharger blowing at 2.8 bar to compensate for the engine’s small 1.6 litre capacity, but future engines were planned to run with Saab’s more familiar turbocharging technology, possibly with an electrically-assisted system. The SVC’s five-cylinder configuration was dictated by the Saab’s width and the need to fit the engine transversely.

A key component in making the SVC work efficiently and seamlessly was Saab’s powerful Trionic engine management system that originally controlled only the ignition, injection and the turbo, but now managed the throttle, and in this case, the tilt. According to Bergström the SVC felt more like a large- and the turbo, but now managed the throttle, and in this case, the tilt. According to Bergström the SVC felt more like a large-capacity engine than a small high-revving 1.6 to drive, and it was accompanied by a sporty engine note.

Whilst the engine tilted through four degrees to give the 8:1 to 14:1 range of compression ratios, this could be altered to cope either with local demands or offer differing driving characteristics. “We can make it an economy engine or a torquey one, whilst reducing the bore would make it higher revving,” said Bergström at the time.

Although a number of prototypes were built and tested, the SVC never reached fruition and died with the company in 2010.
Improving urban air quality is the major impetus for a continuing push towards monitoring and regulating particle emissions. Now attention is extending to include particles significantly below the threshold of current regulation, approaching the molecular range – and Ricardo is spearheading some of the latest research in this area as well as helping industry comply with existing and future regulation. Anthony Smith reports

In the continuing endeavour to control harmful emissions from motor vehicles, the measurement of particle numbers (PN) is now firmly a part of the European regulatory framework. The introduction of PN standards followed the pioneering work carried out by Ricardo and its partners in the early 2000s under the then UN-ECE GRPE (United Nations Economic Commission for Europe Groupe des Rapporteurs pour la Pollution et l'Energie) Particle Measurement Programme (PMP), an organization later brought under the auspices of the European Commission.

This ground-breaking initiative moved the application of particle emission control science on: as well as measuring the mass of particles, the approach was expanded to include the monitoring of individual particles.

Regulations now prescribe that in addition to meeting the previous mass-based requirement, new vehicles must also emit fewer than 6x10^{11} particles per kilometre over the standard homologation drive cycle (currently NEDC, but to be replaced with the WLTC later in the year). This particle number limit is based on PN measurement above a (non-volatile) particle size threshold of approximately 23 nm. This limit was established both in terms of what was practical to achieve accurately and in a repeatable manner at the time, as well as representing the approximate primary particle size of soot or black carbon emitted as a result of incomplete combustion.

While PN measurement technology for automotive applications remains comparatively new, the particle number limit is also included in the Real Driving Emissions (RDE) element of the WLTP, meaning that the first generation of vehicle-based measurement systems must be PN capable.

While this is leading to a significant effort at supporting the roll-out of PN-based RDE, the very latest studies by Ricardo and its research partners are pushing even further, aiming to resolve particles of a size only marginally greater than the molecular level.

Size rather than mass matters

The need to improve urban air quality is the major impetus for continuing the push towards monitoring and regulating particle emissions down to circa 10 nm, explains Jon Andersson, Ricardo global technical expert for emissions measurement and standards: “There is a growing body of settled scientific opinion that the negative health effects associated with particulate emissions are more closely correlated with either the number of particles or the total surface area of particles, rather than with the overall mass emitted.”
There are in effect two reasons for this. Firstly, for a given mass of particulate emission, a much larger surface area will be available with a greater number of smaller particles than with fewer larger ones. As the particle surface is effectively the transport medium for other compounds generated by, or surviving, combustion, it is not just the particle that can be ingested, but what it carries too. A larger surface area – albeit spread over a greater number of smaller particles – therefore means an increased likelihood of these compounds being ingested.

Secondly, as Andersson explains, while the human respiratory system has evolved to deal with larger particles such as dust or pollens, it is not so well equipped to deal with much smaller ultrafine and nanoparticles. “Nanoparticles can enter the bloodstream directly during respiration through a process of translocation. These circumvent the body’s normal defensive barriers and, once in the circulatory system, they can collect in vital organs such as the brain or liver. There are a whole host of negative health effects that are now being postulated as being attributable to these nanoparticle emissions.”

With the original work of the PMP a decade ago it was recognized that as the recorded mass of particulate emissions goes up, the number might go up too – but that the two do not necessarily always correlate. Number-based metrics were therefore recognized as being far more likely to effectively target the emissions that are most damaging to health. 

**Gasoline is the future focus for nanoparticles**

The original PMP work that led to today’s PN regulations has to a large degree solved the issue of particle emissions from modern diesel engines. While some light duty diesels might have achieved the particle mass requirement without aftertreatment, DPF fitment would be required for all engines to achieve the required PN standard. From Euro 5 onwards, all European light duty diesel vehicles have thus been DPF equipped and, if appropriately calibrated, can generally comfortably also be made to conform to RDE regulations for particle emissions. It is also thought that current DPF technology is good at capturing particles below the existing 23 nm threshold, as the presence of soot already captured within the DPF appears to be a highly effective filter in its own right, substantially exceeding the filtration efficiency of the substrate.

The latest generation of gasoline powered vehicles may be able to meet the existing 23 nm target without applying particle aftertreatment in the form of a gasoline particulate filter (GPF). To investigate the level of sub-23 nm particles emitted by a typical gasoline powered car, however, Andersson and his team have worked with industry body AECC (the Association for Emissions Control by Catalyst) on a project in which RDE measurements of gases and PN were first recorded on the road. These RDE measurements were then reproduced and modified in the vehicle test laboratory where they could be stressed, for example by increasing the dyno load and reducing temperature, and highly accurate PN measurements taken both with and without a GPF fitted.

“We carried out two sets of vehicle measurements,” explains Andersson.

“The first was on the current regulatory level of particles greater than 23 nm, with a second data set measured at 7 nm and upwards. The difference between these two tells us how many smaller particles are being emitted in the size range between 7 nm and the 23 nm lower threshold of current regulations.”

“What we have been able to see is that the GPF tested is more efficient for the smaller particles than for the larger ones. While at first sight that may sound counter-intuitive, there is nevertheless a clear technical logic to it. The smaller particles are being emitted in the size range between 7 nm and the 23 nm lower threshold of current regulations.”

To make the >23 nm measurements a PMP compliant system was used, sampling from the CVS. This is completely in-line with the current regulatory procedure, including a particle counter with 50 percent efficiency for 23 nm PN (efficiency increases at larger sizes). To make the >7 nm measurements a catalytic stripper – effectively a heated oxidation catalyst, used to eliminate volatiles – was used, again sampling from the CVS, with a particle counter with 50 percent efficiency for 7 nm PN. The PMP approach includes a correction for particle losses, and a correction was applied for losses in the catalytic stripper to the 7 nm system results. The two systems (>23 nm and >7 nm) ran simultaneously.

The results showed that without a GPF, >7 nm emissions are substantially higher than >23 nm emissions across several drive cycles and emissions levels. However, from the same vehicle with a GPF fitted, the >7 nm emissions are almost the same as >23 nm emissions. This is a strong indication that the particles between 7 nm and 23 nm, that result in the large difference seen in the non-GPF tests, have been preferentially retained in the GPF, when compared to >23 nm PM (which are measured by both instruments). Thus the filtration efficiency of the GPF is higher for the smallest particles, <23 nm, than it is for particles >23 nm.
particles effectively behave much more like a gas, so they diffuse into the structure of the filter much more quickly than the larger particles. So the GPF gives very effective filtering at this smaller particle size band, even with a filter that is relatively empty of soot."

GPFs work in a similar manner to DPFs. However, there is much less soot mass in the emissions of a gasoline engine, so the amount to be trapped is much smaller. Also, as a gasoline engine has a lean episode every time there is a fuel shut-off, the temperature spike at these frequently occurring conditions is sufficient to trigger soot combustion. As such, soot almost never accumulates in a GPF in the manner that it does in a DPF, and there is no requirement for any form of active regeneration strategy for normal driving.

The results of this work clearly demonstrated that while the test vehicle satisfies current particle emission regulations, it frequently exceeded the $6 \times 10^{11}$ particles per km limit on tests in which the size range of measurement started from 7 nm, demonstrating just how numerous these smaller nanoparticles can be. Conversely with a GPF fitted, the vehicle emitted less than the $6 \times 10^{11}$ particles per kilometre limit for all tests, effectively controlling both the current regulatory size range and the $< 23$ nm particles too.

**New engine technologies, new challenges**

As automakers push to make the gasoline engine ever more efficient, regulators are becoming concerned about this smallest size range of nanoparticles because of a fundamental change in the way that non-combustible compounds are emitted.

As engine-out soot levels are reduced as a result of more efficient combustion, the resulting particle emission is generally comprised of smaller agglomerates within an approximately identical number of particles. Soot agglomerates of perhaps up to 80-100 nm in size will include compounds such as metal oxides that arise from the non-combustible components of the fuel and lubricant additive packs, and engine wear. These compounds of elements such as zinc, phosphorous and calcium have always been present in exhaust emissions,

"Nanoparticles can enter the bloodstream directly during respiration through a process of translocation. These circumvent the body’s normal defensive barriers and, once in the circulatory system, they can collect in vital organs such as the brain or liver" Jon Andersson, Ricardo emissions measurement and standards
and may appear as particles smaller than 10 nm, but they effectively attach to the surface of abundant larger soot agglomerates. The concern with future high-efficiency gasoline combustion is that the inherent lack of soot particle agglomerates in the emissions will result in much larger numbers of independent metal oxide and other near 10 nm particles being emitted.

How low to go?
With widespread and increasing concern over the health consequences of nanoparticle emissions, the European Commission is already supporting further research by Ricardo and other researchers, including the PMP group, into measurement technologies, systems and methodologies that might support a lowering of the current particle number threshold.

Three Horizon 2020 projects are currently being supported in the area of examining how particle numbers can be reliably counted in a repeatable manner below the current 23 nm threshold of regulation. Reflecting the high priority attached to this area of research, the new engine technology projects also being funded under the auspices of the Horizon 2020 programme are to be evaluated at sub-23 nm particle emission levels using the new approaches developed in the particle research projects.

Ricardo is an active participant in the three-year ‘Down To Ten’ project, the main thrust of which is to consider the application of both condensation particle counter and diffusion charger methods of particle counting. Following thermal or catalytic processes by which volatile particles are removed, a condensation particle counting method is used for the current regulatory testing approach. This is based on artificial growth of non-volatile particles by mixing them with a supersaturated butanol vapour and then cooling the mixture. The tiny nanoparticles become nucleation centres for droplet formation and grow to spheres of a size where laser counting is possible.

By contrast, diffusion chargers are based upon the transfer of an electric charge to the surface of the particles, followed by the measurement of charge transferred at an electrometer over which the exhaust is passed. Effectively this approach is an indirect counting method, and tends to be less sensitive than counting the particles. It has advantages too, however, as it is a more practical approach for the type of OBD measurement system that might together on the current research into lowering the threshold of PN measurement, the APMC has developed a market position assisting industry and governments on matters relating to particle emissions, not least in the calibration of the increasingly diverse range of available PN measurement equipment.”

Following the original work of the PMP, draft regulations were introduced by the European Commission and a basic laboratory-scale instrument specification was published. Having worked closely with the PMP on the equipment specification, Marshall’s team were ideally placed to assist test equipment manufacturers in the crucial area of calibration.

“One of the final pieces of work we had completed on the original PMP was to reassure industry that the measurement systems could be calibrated and made reliable,” explains Marshall. “The first company to approach us was HORIBA. We provided some initial support and demonstrated that we could provide calibration services on site at HORIBA customer premises. This significantly improved the operational efficiency for HORIBA’s customers as it avoided equipment being shipped to and from the manufacturer, hence minimizing the disruption to test operations.”

Calibration process
PN measurement systems are calibrated using carbonaceous particles produced by the controlled combustion of propane. A known sample of a defined narrow particle size band is selected and conditioned at high temperature to ensure thermal-stability, and this becomes the calibration aerosol. The instrument under calibration samples the calibration aerosol simultaneously with one of the APMC’s own instruments that has itself been calibrated at the National Physical Laboratory (a process carried out annually), to provide complete process traceability.

The Ricardo APMC is the only UK-accredited (to ISO 17025)
eventually form part of the production vehicles’ monitoring systems.

“It’s important that we can explore both of these measurement technologies in Down To Ten,” explains Andersson, “as there is clearly an overlap of requirements between the test laboratory, RDE, and through-life vehicle OBD-based compliance monitoring. The outcome of the current horizontal Horizon 2020 projects looking into this subject should provide a thorough basis on which regulators can make decisions regarding any future lowering of the current 23 nm particle threshold – including just how low the new limit needs to be – as well as the measurement systems and methodology that will be needed to ensure that the limit can be enforced.”

Work on the Down To Ten project has only just started, but it builds upon previous efforts by Ricardo and the PMP team examining sub-23 nm particle emissions, as well as the 15 or so years of research that led to the original regulatory regime that has been so effective in reducing the particle emissions of modern diesel engines. With the proactive approach being adopted by the European Commission, a modified framework may well be in place to address the nanoparticle emissions of next-generation high-efficiency gasoline engines as these become an increasingly important part of the powertrain picture.

Ricardo APmC services

- Measurement system calibration
- Filter performance testing
- Designing and validating stack samplers
- Particle spatial distribution mapping
- Particle temporal distribution
- Particle abatement strategies, policies and actions
- Training and capacity building
- Bioaerosol monitoring, risk assessment and advice
- Nuisance dust assessment
- Smoke generator validation
- Instrument hire of a range of specialist particle measuring equipment

A major aspect of the work of Ricardo’s Airborne Particle Measurement Centre (APmC) is in the calibration of particle measurement systems, both as used in vehicle testing laboratories (left) and in the PEMS equipment used on highway tests (below).

Ricardo APmC services

Marshall believes that the current interest in ultrafine and nanoparticle emissions will grow still further as the awareness of the risks of this form of pollution increases. “We’re receiving interest from places like airports, where we’ve looked at everything from passing traffic, passenger vehicles arriving at the airport and trucks delivering freight, to airside service vehicles such as aircraft tugs, fuel bowser, and even emissions from the aircraft themselves such as the APU systems that can be run continuously while the plane is on the ground.”

While the current focus is upon emissions resulting from combustion, Marshall is quick to point out that this is not the only source of vehicle particle emissions – and that vehicles are not the only sources of particles. The APMC therefore stands ready to provide consulting services around all or any of these.

So while Ricardo’s emissions research teams are spearheading the pushing of the boundaries of particle measurement to encompass the smallest of nanoparticles in the regulations and measurement systems of tomorrow, the company’s particle emissions consultants are also able to tackle the problems of particle emissions based pollution wherever it occurs today. This unique combination of skills and expertise provides Ricardo with operational and research synergies in both disciplines which are of value to its customers in the crucially important field of particle emissions control.
Following the acquisition of a renowned industrial and motorcycle design operation, Ricardo can now provide a fully integrated product creation service from first ideas to final production sign-off. This, as Tony Lewin reports, signifies a strategic expansion beyond engineering and technology to become a provider of complete products.

When Ricardo Motorcycle took full control of Exnovo in July 2016, it was acquiring much more than an already highly regarded motorcycle development organization. For while the Italy-based consultancy is indeed an acknowledged leader in the two-wheeler sector, with a portfolio that includes high-profile models such as the BMW C600 luxury scooter, it also possesses a far broader design capability that extends into almost every aspect of modern life and leisure.

With a client list stretching from Mahindra to Renault, Ducati to Datalogic and BMW to Japan Post, the newly acquired division of Ricardo Motorcycle has a wide-ranging product and industrial design skill-set that dramatically expands the capabilities that Ricardo can offer its customers. And, crucially, it raises Ricardo’s game from technology and engineering to that of a full-spectrum provider of the complete product creation process.

Paul Etheridge, head of sales at Ricardo Motorcycle, quotes a recent project example to illustrate the clear benefits of the new in-house industrial design capability. “We recently designed a general-purpose engine for an Indian customer,” he says. “That’s normal bread-and-butter business for Ricardo, but in this case we added on our new industrial design skills and also designed the enclosure the engine goes in. So for just a small supplement to the cost our customer got a complete product, and not just an engine that they then had to put into the product themselves.”

The benefits of this approach are strikingly clear. In addition to its core business of developing technologies, components and systems, Ricardo can now create complete products –
even multiple products – from initial concept to commercial readiness. It can encompass market research, product definition, aesthetic design, engineering, bill of materials management, prototype build, testing, cost analysis and procurement, and even the design of spin-off accessories. This is a fundamental shift in strategy and one which, says Etheridge, will be extended outwards to the rest of the Ricardo organisation.

What is more – through its Performance Products division, which produces advanced engines for customers including McLaren, as well as transmission and driveline systems for Bugatti and many motorsports clients – Ricardo can also provide high-quality niche manufacturing capabilities for a wide range of products: this division even supplies aerospace components for Airbus.

Ricardo Motorcycle’s acquisition of Exnovo brought high-level design expertise, with clients including Bimota (above) and Adiva (left) as well as BMW and several Asian manufacturers.
Industrial design for integrated cities

The expansion into flexible and broad-based industrial design is especially important in today's uncertain markets. Already more than half the world's population live in urban areas, compelling governments to come up with strategies for eco-friendly mass transportation across extended urban landscapes and blurring the boundaries between private and public transport, and individual and shared ownership.

Urban mobility is becoming a steadily more important focus as the populations and radii of cities increase, air quality constraints tighten and more and more authorities impose permanent or time-based city-centre bans on combustion engine-powered cars and motorcycles. Many cities will develop mobility schemes, and many of these solutions will have to be tailor-made to the local conditions and resources too.

Ricardo is ideally placed for this upcoming revolution in all aspects of mobility – not just in the traditional areas of vehicle and propulsion system design, but also in the wider scope of the services that give access to these vehicles and the much broader configuration of the whole transportation ecosystem in which the new mobility concepts will operate.

A fresh approach to vehicle design

Ricardo’s combination of motorcycle and, now, industrial design expertise provides the perfect background for the development of both the new generation of urban mobility vehicles and the system itself. Massimo Lotti (see box on page 22) is head of motorcycle development at Ricardo Motorcycle’s design centre in Rimini on Italy’s Adriatic coast, and brings many years of experience to bear when it comes to visualising and conceiving the light and middleweight vehicles that are likely to dominate future urban landscapes.

“These vehicles will combine design elements drawn from both the car and motorcycle segments,” he says, “and in our experience it is much better to introduce a real vehicle on the market by approaching the design from the motorcycle side.” In particular, explains Lotti, the business case is more straightforward using the motorcycle starting point: “It’s easier to innovate when you start from something simpler – you can respond more quickly, and the investment and production volumes don’t have to be so high. I’m expecting the first vehicles connecting these two worlds to be really innovative, and that comes best through our approach. We are in a good position.” The approach taken by carmakers, on the other hand, is less compatible with this new market sector, certainly in its early years: automakers’ start-up costs are high, their time to market is comparatively long and, says Lotti, the car companies would find it hard to make a business case for volumes as low as 5000 or 10,000 units a year.

“To make a real product, with the right price, in the right numbers, and with a solid business case, this is only possible using motorcycle techniques,” he concludes. “Of course, sooner or later, cars will enter that market – but it will take a lot more time.”
Product definition
Forming a clear picture of a potential new product several years ahead of launch is always a tricky business. The market is sure to have evolved, new competitors may have appeared or technologies and regulations may have moved on. However, conceiving a totally new product in fresh market sector that does not yet exist – that takes a still greater leap of imagination, and this is precisely the position when it comes to urban mobility vehicles. Very few people can project themselves into a future scenario with such different priorities, but this is precisely the task that Massimo Lotti and his team specialize in.

With electric scooters and three-wheelers, for instance, the shape and size of future battery systems will have a big influence on the vehicle’s weight and packaging, and designers must project the evolution of consumer preferences and what will be the most important qualities that help buyers to regard a new-style vehicle as a viable replacement for the owner’s second car – a vital prerequisite for success in the new sector. Lotti cites the Renault Twizy as a brave attempt but a less than successful between-segments vehicle: it is too wide to thread through traffic, yet it also has several of the drawbacks of a motorcycle.

The familiar example of the BMW C-series luxury scooter, where Lotti and his team handled the entire vehicle definition and development programme, shows the value of a thorough clean-sheet process. BMW had wanted to enter the market with a single scooter with a sporty flavour; after market research, the Italian team advised a multi-model approach with a single platform providing multiple variants.

The programme for Japan Post (right) shows a similar set of benefits resulting from an open-minded approach. Here, when asked by Japan Post to come up with a concept for an urban delivery vehicle, Ricardo Motorcycle’s design operation was able to draw on research it had already undertaken for the Italian and French postal services. “We began by interviewing the postmen,” says Massimo Lotti, head of design, “and we asked how they did their rounds and what they preferred. One of the first things we discovered was that they did not want doors – these would make it slower to get into and out of the vehicle.

“We also established that the maximum typical daily mileage was about 20 km but that there were about 100 to 200 stops and starts each day,” he adds. “So we focused much more on these than on maximum range, and we also had to cater for a load of 100 kg in the cargo area.”

The concept that resulted from these requirements was a three-wheeler with two wheels at the rear, and capable of tilting on corners so as to preserve stability and keep overall width narrow enough to thread through traffic easily.

A roof structure was added for weather protection and security, and this had an unexpected follow-on benefit, much to the delight of Japan Post: the company’s insurance premiums were actually reduced because of the greater safety now enjoyed by its delivery personnel.
market studies determined the daily operational range required, and thus the size and weight of battery; this then helped identify the optimum vehicle configuration.

“Our strength,” says Lotti, “is that we are fully integrated between styling and engineering. We all work together in parallel.”

“When we have to create a guideline or a product brief,” he continues, “we try to merge the marketing aspects with the technical. We analyse the trends, determine the best market positioning, research ergonomics, styling and environmental factors. This gives us the technical layout and leads to concept engineering: this, too, is a creative phase just as well to engineering as to styling. We’re very flexible: we don’t have a fixed list and we can change our approach for each customer.”

**Market evolution**

There is no such thing as a typical bike or standard customer in the motorcycle segment; even the segment itself is hard to define as it takes in everything with two, three or even four wheels, from cheap 50 cc scooters to heavyweight US-style cruiser bikes, and from battery power to highly tuned gasoline engines delivering well over 200 hp. Yet several broad trends have been evident in recent years: the growth in the market for light scooters as commuter vehicles; large numbers of electric two-wheelers in Asian markets; the popularity of adventure-style motorcycles in the larger capacity classes; the emergence of an elite super-sports and super-luxury bike market, and the rise of luxurious premium scooters as an important niche.

However, the scooter market has recently begun to level off, at least in Europe, says Lotti. “Now it is the very cheap and very expensive motorcycles that are expanding, and this is hitting some scooters; for half the price of a premium maxi-scooter you can buy a real 600 cc motorcycle.”

Further uncertainty comes from the upcoming Euro 5 emissions regulations which will apply to the two-wheeler sector from 2020. Euro 4 norms have just come into force this year, but Paul Etheridge warns that the next set of standards will be a much harder challenge. “Euro 5 will be a very significant further step: it includes On Board Diagnostics, and everybody is worried about it. But with our wide-ranging automotive experience coupled with our sharp focus on the needs of the motorcycle and scooter market, this is an area in which we are ideally placed to assist.”

With increasing interest in zero emission electric power, however, both Lotti and Etheridge are very clear about one trend: battery power may become important in the scooter market, but motorcycles will retain their internal combustion engines for much longer. “Motorcycles are driven by emotion,” says Lotti, “and buyers will stay loyal to the

**Ingenuity and imagination in design**

The BMW C600/C650 series premium scooter is one of the most intricate examples of component packaging ever seen in the automotive business, whether on two wheels or four. Tucked away within its open, step-through frame are not only a twin-cylinder engine and its associated induction system, radiator and CVT transmission but also the exhaust and catalyst, the rear suspension strut and swinging arm, the ABS unit, the fuel tank and all the electronic control units, wiring and cabling.

But where the BMW goes a step further in its ingenuity is in providing clever solutions for customers with high expectations. Massimo Lotti – head of motorcycle development, Ricardo Motorcycle design centre, Rimini, Italy – is especially proud of the helmet storage system he and his team developed for this premium scooter. “We have two patents with BMW on the big scooter, in fact,” he says. “In this segment you need to provide for two helmets, but on a sporty scooter like this you have a short tail fairing. So we had to find a trick to house two helmets but to keep the small tail unit.”

The breakthrough, says Lotti, came with the realization that the only time that both helmets needed to be stored was when the scooter was parked. “So our idea was to make use of the space normally taken up by the rear wheel’s suspension travel. When the scooter is parked, the storage box expands into the wheel travel area, allowing the second helmet to fit inside.”

The second patented innovation is the side stand linked to a parking brake. When parking on a slope, high-mass two-wheelers need to be left in gear to prevent rollaway, but the CVT transmission of a scooter does not allow this. “So you need a parking brake,” explains Lotti. “There are many systems from other manufacturers in this area, but with our patented innovation you simply put down the stand, park, and it locks the brake.”

**“Euro 5 will be a very significant further step: it includes On Board Diagnostics, and everybody is worried about it”**

Paul Etheridge, Ricardo Motorcycle head of sales
character and the brand significance that gasoline engines provide. But a scooter is a more functional choice – it has better protection, better load capacity and greater convenience. The type of engine is much less important, so that’s where electric power will advance most.”

Price will play its part here, observes Etheridge: as soon as electric powertrains achieve cost parity with traditional engines they will begin to dominate the urban environment. But for tomorrow’s city commuters there is no question of combustion engine power: this upcoming generation of urban mobility vehicles must by definition be super-clean in every respect – and that means electric operation. And as the ambassadors for an entirely new segment midway between cars and motorcycles these new-era models must be appealing enough to persuade people out of their cars. So they will need to combine the advantages of both: the agility, economy and environmental compatibility of a bike, linked to the convenience, safety and practicality of a car.

“With motorcycle design we have a lot of freedom to come up with the innovative concepts needed for this new era of mobility,” observes Lotti. “There are fewer rules, and it is easier to play around with truly imaginative ideas.”

Outlook
In today’s closely connected world, with vehicles and individuals in constant communication with electronic networks and the giant electronics companies forging closer ties with automakers, the value of a joined-up approach to new ventures is being clearly demonstrated. And on a smaller but no less important scale, the same thinking applies when it comes to product creation. The increasing interdependence between every element within tomorrow’s multi-modal transport systems makes an integrated, system-wide design approach imperative; and with such a wide range of specializations now in play, it makes sense to locate those skill-sets under the same roof to allow ideas to cross-pollinate.

With 23 years’ product development experience – 19 years of which have been spent in the motorcycle industry – Massimo Lotti is one of Italy’s most respected industrial and vehicle designers. Previously head of industrial design and motorcycle development at Ugolini Global Design and teacher of industrial design and surface modelling at Politecnico di Milano, Lotti was a founder and head of vehicle development at Exnovo, the company which became a part of Ricardo Motorcycle following its acquisition in 2016.

Massimo Lotti – head of motorcycle development, Ricardo Motorcycle design centre, Rimini, Italy

With the advent of a fully integrated industrial and product design capability, encompassing every step of the creative process from the earliest ideas to the final production sign-off, Ricardo’s move is both well timed and of great significance. Now with the ability to provide complete products rather than simply the technologies that underpin them, Ricardo Motorcycle is ideally placed to answer the call for joined-up thinking in every area of design – most notably in the exciting new segment for urban mobility vehicles, where those many years of experience in innovative motorcycle design can be used to best possible effect.
The recently completed ULTRAN project has demonstrated the value of following a systems approach to the process of lightweight driveline design, in the case of an advanced rear drive unit designed and prototyped by Ricardo, offering a 24 percent reduction in mass without compromising performance. **Anthony Smith** reports...

The ULTRAN project, which stands for ultra-lightweight transmission and driveline, has been a three-year research initiative led by Jaguar Land Rover in a consortium including Ricardo, Tata Steel, Lubrizol, DRM Consulting Ltd, American Axle & Manufacturing and the Universities of Southampton, Newcastle and Warwick – with the support of the UK’s innovation agency, InnovateUK. The results of this work were reported in detail for the first time at the CTI Symposium, Berlin, in December 2016.

“The project set out to accelerate the processes of designing, developing and validating cost-effective lightweight drivetrain technologies, aiming to significantly push forward the practical application of reducing the mass of driveline systems and components,” explains Ulf Herlin, head of the Ricardo Driveline and Transmission Systems Product Group. “We selected the latest generation Range Rover as the baseline vehicle for the research, demonstrating the very aggressive weight saving targets the project was seeking, given that this baseline vehicle had already been the subject of extreme mass reduction, being a full 16 percent lighter than its predecessor.”

Ricardo led the concept generation through to the manufacture and testing of the ultra-lightweight rear drive unit (RDU), which was a major focus of the ULTRAN project. A like-for-like replacement RDU for the production version was designed – meaning that it would be fully interchangeable with the existing unit, using, for example, the same mounting points, the same interfaces, and designed to unchanged torque capacity and durability targets. At an early stage of the work, it was established that more mass could be saved if the boundaries of the study were to include changes to the mounting points, but it was decided that sub-frame modifications were beyond the scope of the ULTRAN project.

### Systems perspective on mass reduction

Once the boundaries were set, the engineering team took a system view of mass reduction, as opposed to working on a piecemeal, component-by-component basis. Applying Ricardo’s systems approach, the starting point of the design of the new RDU was the basic specification requirements such as the intended torque capacity and packaging constraints. Based on a review of the state of the art for the system under consideration, concepts were brainstormed and then ranked, using an analytical hierarchy process, against a matrix of priorities such as manufacturing cost, mass, operational efficiency, NVH, package volume and performance. In each case, the concepts were scrutinised in terms of available improvement options such as the ability to eliminate or combine components to save mass, reduce size, or apply improved manufacturing technology, materials or processes.

Once the most attractive concept had been identified then detailed engineering design could be progressed with confidence that it will be both functional as well as delivering on the required improvement objectives; in this case, primarily, of saving weight.

### Clean sheet design

Applying this systems approach to achieving a low mass, the design of a revolutionary new RDU concept, now subject to a pending Ricardo patent, was delivered. The unit is based around a lightweight differential mounted within an innovative, compact, single-piece skeletal casing with tough, low-density lightweight plastic covers. The form of the skeletal design originated from finite element-based...
simulation and topology optimization. Using this data-driven template, the skeletal design could then be developed in CAD, based on a single integrated aluminum die-cast structure, with closures and fluid seals formed by the lightweight plastic cover assemblies.

“Using this systems approach to lightweighting, the Ricardo engineering team eliminated internal parts and simplified those remaining, while maintaining comparable performance or improving upon the baseline design,” explains Herlin. “The very impressive 24 percent – a full 8.5 kg – mass saving of the complete unit was achieved approximately equally between the gears and shafts, and the casing system.”

The conventional differential carrier has been eliminated with the crown wheel supported in a double-row angular contact bearing, and differential gears supported directly within the crown wheel. The bearing is a bespoke, asymmetrical design created specifically to support the loads from the crown wheel. Face gears were used because they gave proportions which fitted better with the rest of the design; however, conventional bevel gears could also be used. A hollow pinion shaft was designed and manufactured, delivering a mass saving of 1 kg for this component alone. The single crown wheel bearing is also key to enabling a further innovation in the form of the integrated structural casing which is formed of a single casting. This has no stressed bolt flanges adding inefficient mass – as would be the case in a traditional two-piece clamshell design – and can offer improved NVH from increased stiffness. The closures of the unit are formed with plastic injection moulded covers, each featuring a contoured sealing surface with the cover retaining the internal lubricating oil and preventing dirt and water ingress. The covers also provide a degree of impact resistance from foreign bodies and the lower cover can also act as a vehicle jacking point. As they are not key to the structural performance of the unit, only a relatively low-strength, compliant joint to the structural component is needed, sufficient to perform the sealing function. The side gears, with their integrated CV joints and hollow pinion shafts, are independent of the other design innovations, but were included to demonstrate the maximum mass reduction possible. It would be possible to omit some of these features; for example, using a conventional solid pinion shaft would obviously reduce cost, but in the case of the side gears, at least an additional spline interface would be created which may offset some of this cost saving.

The pinion bore is limited by stiffness not strength; a fully stress-optimised shaft was initially designed, but analysis showed that this could result in excessive gear misalignment. Overall, the RDU concept generated additional package space from both the side gears with integrated CV joints and the new differential design. The project team identified that this additional package space might allow the creation of single- and multispeed electric axle variants of the concept should these be required.

Testing
Following the completion of the detailed design for the lightweight RDU, drawings were issued and six of the new lightweight RDUs were procured, assembled and then tested at Ricardo. These were evaluated by Ricardo through a rigorous programme of high torque testing, lubrication testing at different angles on a tilt rig, efficiency and durability testing on a “3E” test rig. Through these evaluations, the prototype unit demonstrated its functionality with comparable performance to the current production unit.

In addition to the functional testing of the units themselves, testing of the RDU in the form of a TRL-5 vehicle prototype in a Range Rover was undertaken by ULTRAN project leader Jaguar Land Rover and fellow partner, the University of Southampton. This was performed with professional drivers on three routes near the JLR Gaydon test facility, and confirmed that the lightweight design would not cause adverse affect to vehicle ride quality.

Transmission casing
In a separate part of the ULTRAN project, Ricardo engineers also applied the same systems approach to lightweighting in designing a six-speed manual transmission casing. In this instance, in a design also the subject of a Ricardo patent application, a weight saving of 1.9 kg (16 percent) was achieved in comparison with the baseline.

“The Ricardo contribution to the ULTRAN project has demonstrated the very significant opportunities for driveline lightweighting that can be realized when a systems approach to product design for mass optimization is applied by our highly experienced and creative engineers,” concludes Herlin. “ULTRAN set very ambitious goals by defining as its baseline vehicle a product that in many respects represents the current state of the art in terms of driveline mass reduction. By applying the methodologies demonstrated in the ULTRAN project, we have shown that significant further mass reductions – with consequent improvements in vehicle efficiency and CD savings – are possible at comparable cost and performance to existing production, based on market-ready materials, processes and design technologies.”
Future combustion technology collaboration

Ricardo has joined a strategic partnership led by McLaren Automotive, which aims to design and develop technology for the next generation of high performance, low carbon powertrains. It also aims to further facilitate CO2 reductions while simultaneously increasing engine output. The technology is destined for application in future McLaren engines in a project supported and part-funded by UK Government through the Advanced Propulsion Centre (APC) – with balancing contributions by the project partners.

Ricardo and McLaren Automotive will be joined by BMW, while Grainger and Worrall will deliver complex, lightweight casting technology. Lentus Composites will contribute knowledge in specialist composite structures, and the University of Bath will bring its advanced research and development capabilities in internal combustion engine systems efficiency.

10,000th car – and Ricardo-built engine
Ricardo is the longstanding engine manufacturing partner of McLaren Automotive, having previously also collaborated on the design and development of the McLaren M838T engine which has enjoyed multiple category wins in successive International Engine of the Year awards.

The phenomenal and growing success of McLaren Automotive since it began production of its first 12C car in 2011 was demonstrated with the company passing the milestone of its first 5000 cars in 42 months; just 22 months later, in December 2016, McLaren built its 10,000th vehicle.

At the heart of Ricardo’s support for McLaren is the Ricardo High Performance Assembly Facility at Shoreham-by-Sea – an advanced, quality-focused production facility. Incorporating the very latest thinking in high-quality manufacture and operating within a strict ‘no faults forward’ culture, this impressive facility has expanded its capacity and production rate in tandem with McLaren Automotive’s own Production Centre. Since a major expansion formally opened at the start of 2016, the facility has included a range of new laboratories and workshops capable of supporting prototype engine builds and advanced metrology; a second dynamometer is capable of simulating real-world load conditions and of testing engines across the full range of power outputs.

Shengrui 8AT success
The award-winning 8AT eight-speed automatic transmission is the result of a highly successful collaboration between Ricardo and Shengrui, a leading Chinese manufacturer of transmission and driveline systems and components. Ricardo took engineering responsibility from concept to pre-production prototypes, including responsibility for software and production calibration.

In January Shengrui, based in Weifang, Shandong province, was recognized with the National Science and Technology Progress Award – one of China’s highest honours in the science and technology sector – for the 8AT. This was a very public acknowledgement of the success of this product, which in 2016 passed the production milestone of 100,000 units. Since its initial development, the Shengrui 8AT has become one of China’s most successful driveline technology products, being applied to 14 different vehicle types across many indigenous Chinese and joint-venture vehicle brands. The company is also targeting an increase in production capacity to provide a volume by 2020 of one million units per year.
Ford Performance wins Ward’s 10 Best Engines of 2017 award

On January 11, Ford Performance received a Ward’s 10 Best Engines of 2017 award, as selected by WardsAuto editors, at a ceremony held at the Marriott hotel at Detroit’s Renaissance Center. The award was in recognition of the four-cylinder 2.3L turbocharged DOHC engine of the Focus RS, an advanced engine developed in an engineering partnership between Ford and Ricardo.

“This impressive engine was a very effective engineering partnership, with highly motivated engineers from Ford Performance and Ricardo working together to create this world-class, fuel efficient, fun-to-drive, performance power unit for the latest generation of Ford’s iconic Focus RS,” said Steve Sapsford, director of business strategy for Ricardo UK.

As an engineering partner to Ford Performance, Ricardo held responsibility for the engineering delivery of the upgraded engine components and associated systems from concept through to the 90-day point following the start of production. A collaborative approach required close interfacing with global powertrain engineering teams, manufacturing teams, engine and vehicle testing teams, suppliers and calibration teams.

The result of this highly successful collaboration between Ricardo and Ford Performance engineers saw the upgrade of the Ford 2.3-litre turbocharged direct-injection EcoBoost engine deliver an awesome 350 horsepower at 6000 rev/min, matched with up to 470 Nm of torque (during overboost operation) throughout the majority of the engine operating speed range. This advanced EcoBoost engine’s revolutionary technology incorporates direct fuel injection, twin independent variable camshaft timing and a twin-scroll turbocharger, along with further improvements to the base engine to handle the increased thermal and mechanical loads.

Ricardo and LIFT collaborate on HMMWV stability improvements

Ricardo Defense Systems is participating with the Manufacturing USA Institute LIFT (Lightweight Innovations For Tomorrow) in a $7.5 million joint project to address persistent rollover issues related to the US Army’s High Mobility Multipurpose Wheeled Vehicle (HMMWV). The initiative’s goal is to identify and deploy a new, robust, reliable solution to documented braking and stability problems in the current HMMWV configuration.

Ricardo has developed a modified commercial off-the-shelf ABS/ESC system for the HMMWV (see RQ Q3, 2016). LIFT will help support further development of the Ricardo system while also examining light weighting system components with advanced casting techniques and metal matrix parts.

The Ricardo system is currently being piloted in 10 vehicles with the Michigan National Guard. The project will expand the National Guard pilot programme to include production grade components and the development of processes.

Training and additional workforce development will be conducted during integration of the brake kits onto Michigan National Guard HMMWVs. The project team is also working toward building additional test-dedicated HMMWVs to conduct shake, roll and abuse tests and road durability evaluation at the Chelsea Proving Grounds in Chelsea, Michigan; there will be a limited operational review at Camp Grayling, also in Michigan.

Atmospheric Emissions Monitoring

Ricardo Energy & Environment has been reappointed as the UK’s National Atmospheric Emissions Inventory (NAEI) agency on behalf of the Department of Business, Energy and Industrial Strategy – a position that the specialist air quality consultancy has occupied in various forms for more than 20 years.

The NAEI gathers and compiles data on greenhouse gas and air pollutant emissions from a variety of UK sectors, including waste, industry, agriculture, forestry and transport. The data are used to provide insight into the effectiveness of policy, to monitor progress against emissions targets, to demonstrate compliance with international legislation and, ultimately, to safeguard the health and well-being of the UK’s population and the environment.

The data also underpin high-profile obligations of the UK Government, including its commitment to the United Nations Framework Convention on Climate Change to reduce emissions of greenhouse gases as part of the global effort to minimise the impact on human-induced climate change. Data are also used by the United Nations Economic Commission for Europe to estimate air pollutant emissions as part of the monitoring regime for the National Emission Ceilings Directive.
Ricardo to provide hypercar transmission

Unveiled for the first time in mid-2016, the AM-RB 001 hypercar is the product of a unique innovation partnership between Aston Martin and Red Bull racing, combining the vision and skills of two world-leading brands to create a road car the like of which has never been seen before. At the Geneva motor show the car was given the official Aston Martin name Valkyrie.

The AM-RB 001 – known as the Valkyrie – is intended as a car engineered to be entirely useable and enjoyable as a road car, but with the capability to perform like no road car before it on a race track. A maximum of 150 roadgoing Valkyries will be built, including all remaining prototypes, with 25 additional track-only versions. First deliveries are due to start in 2019.

Building upon its strong reputation in the design, development and manufacture of the advanced transmission and driveline systems for some of the world’s highest performing supercars, Ricardo has been selected by Aston Martin as technical and supply partner for the car’s transmission.

The all-new, bespoke seven-speed paddle-shift transmission is being designed and will be manufactured by Ricardo in accordance with Red Bull Advanced Technologies’ specification, channelling the awesome power of the Valkyrie’s 6.5-litre naturally aspirated Cosworth V12 engine. Conforming to the radical hypercar’s ethos of minimal mass and maximum efficiency, and led by Red Bull Advanced Technologies’ simulation work, Ricardo will deploy intelligent engineering solutions to achieve Red Bull’s uncompromising goals.

“I am extremely pleased that Aston Martin has selected Ricardo as technical and supply partner for the transmission of the new Valkyrie hypercar,” commented Ricardo Performance Products managing director Mark Barge. “Since the first hypercars were developed, Ricardo has been at the forefront of transmission design, often leading with advanced and innovative technologies for this sector. The partnership with Aston Martin on the Valkyrie transmission announced today marks the start of an exciting new chapter in which we will contribute to one of the most exciting and innovative cars ever created.”

Celebrating the past – focusing on the future

The Ricardo Centenary Innovation Centre is an impressive facility that provides unique insights into the company’s first century of innovation – and offers an impressive new conference and exhibition venue.

The new 400 square metre facility at Ricardo’s Shoreham headquarters was opened in late 2016 to meet the group’s need for an events, exhibitions and training facility, as well as to provide a resource that can be used by external customers. Representing an investment by Ricardo of circa £1.2 million, the purpose-designed centre provides an attractive and highly flexible open-plan space and adjacent private meeting rooms that are light, airy and beautifully appointed.

Equipped with state-of-the-art audio-visual equipment, the Centenary Innovation Centre can host events for up to 130 delegates with the facility configured with theatre-style seating. As many of the events held in this new space will have an industrial, scientific or academic context, some customers may elect to retain some of the Ricardo exhibits for general interest or as talking points during break-out or refreshment periods for their delegates. The main auditorium is a highly flexible space that can be configured to the precise requirements of any event. In addition to ‘open’ and ‘closed’ stage theatre-style configurations, the facility can also be arranged in herringbone or conventional classroom style, or in a boardroom format for up to 50 people.

Ricardo’s Centenary Innovation Centre has already hosted a wide range of events, both internal to the company and for external customers. These have ranged from international industry seminars and conferences and a meeting of the Greater Brighton Economic Board, through to some of Ricardo’s own local STEM outreach events for local schools and colleges.
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Formula 1 is unrivalled in every aspect of high-performance motorsport – the speed of its cars, the demands of its tracks, the quality of its drivers and the secrecy surrounding its customers and technologies.

Ricardo can’t tell you about the specifics of its 20 year history supplying the very best teams in Formula 1 with the most successful transmission technologies.

We definitely can’t tell you about the components and transmissions we supply, or the teams we supply them to, or the numerous drivers and teams we’ve supported to victory. We can’t tell you about the breakthrough materials and advanced machining equipment we use to deliver products for these extreme-sport applications, either. We can’t even tell you who, within our unrivalled team of UK engineers, works tirelessly to ensure every design is optimized to deliver unmatched performance, over the shortest lead times in the market.

What we can tell you, however, is that our capabilities will deliver you a clear advantage across key components in the covert world of Formula 1.

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