LOTUS ENGINEERING

proActive
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Welcome

Group Lotus is seeing some exciting new changes as it enters the new decade. CEO Dany Bahar has strengthened the senior management team with a number of new faces who bring a wealth of experience from many major players in the global automotive industry. As part of this, Lotus Engineering welcomes Dr Robert Hentschel as its new director responsible for continuing the growth of our engineering consultancy and technology business.

The whole industry also continues to change faster than ever. While in recent months the economic situation has had a serious impact on some major brands, CO_2 reduction remains the primary force reshaping the automotive landscape. More stringent emissions levels are central to that but it is not always clear exactly what the legislation says and how it will work. In this issue, from the perspective of Lotus as a small-volume manufacturer, Simon Wood discusses how the new regulations have come about and what their effect will be over the coming years.

New legislation is usually perceived as a problem that car manufacturers are constantly struggling with, but for Lotus Engineering it presents many opportunities; our expertise in alternative fuels, downsized engines, hybrids and electric vehicles and lightweight architectures are all in high demand from clients needing support to continue the downwards emissions trend. However sometimes bigger steps occur when a new direction is taken that challenges conventional thinking. It is accepted that downsizing is the route to more efficient combustion engines, right? Jamie Turner discusses how, by taking a new approach, upsizing might be the new downsizing. Find out inside why this is not as crazy as it sounds.

Peter Morgan
Marketing Manager – Lotus Engineering

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INDIA: Carl-Peter Forster appointed CEO of Tata Motors

Tata Motors has appointed Carl-Peter Forster as group chief executive officer of the company. He will have overall responsibility for Tata Motors' operations globally, including Jaguar Land Rover (JLR).

Forster left his previous job as CEO of General Motors Europe (GME) last year after GM's board opted to cancel the planned sale of Opel to Magna in favour of retaining the unit. Forster had publicly backed Magna's bid during the protracted negotiations and political controversy surrounding the German government's apparent support for the Magna bid.

Forster was said to be being lined up for a senior job within Tata Motors following the departure of JLR CEO David Smith in January. Loss-making JLR is expected to figure prominently in anglophile Forster's in-tray.

Forster, 55, has 24 years of international experience in the automobile industry. Most recently he was the head of General Motors, Europe, where he looked after Opel/Vauxhall, Saab and the European activities of Chevrolet. Before joining General Motors in 2001, Forster had 13 years' experience at BMW where he held various positions including that of managing director of BMW South Africa and was also on the managing board of BMW responsible for manufacturing.

Tata Sons and Tata Motors chairman Ratan Tata said: "Tata Motors expects that Mr Forster's induction will greatly facilitate its ambition towards being a truly international company."

A Tata spokesman later told just-auto the decision whether to appoint a new JLR CEO was still to be made.

Source: just–auto.com editorial team

US: Nissan EV purchase process outlined

Nissan has announced the purchase process for its Leaf electric car in the United States. Prospective purchasers already can register on the automaker's website, with 50,000 signed up to date, and they'll get first priority when the "reservation process" begins in April, soon after the EV's price is announced.

Prospective buyers will pay a refundable US$100 reservation fee and Nissan will begin taking firm orders in August, for deliveries when sales begin in the owner's particular market. Sales begin in the selected initial markets from December 2010, with vehicles "available in all major launch markets quickly thereafter", the automaker said.

"The [Leaf] purchase process is effortless, transparent and accessible, offering value with a one-stop-shop approach for everything related to the car, including the assessment, permitting and

installation of in-home battery charging units," said Nissan Americas chairman Carlos Tavares.

Nissan has also started a global marketing campaign for the EV using the tagline 'The New Car'.

A promotional tour covered 10,000 miles in the United States and Canada, providing the first opportunity for more than 100,000 people to see and learn about the EV.

"There was a groundswell of grassroots support from coast to coast," said Tavares. "Everywhere we went, people recognised a new form of mobility - a turning point - and they wanted to be a part of it. The response was spontaneous and diverse. We were joined by mayors and government officials, CEOs, utility partners, car enthusiasts, students, dealers, media, environmentalists, Twitter users and lots of families."

Stops included the Oregon State Museum of Science and Industry in Portland and a charging station equipped McDonald's in Cary, North Carolina. The tour also also stopped at Nissan Americas' HQ in Franklin, Tennessee and the Smyrna, Tennessee, factory which will build the Leaf for North America from 2012.

Source: just–auto.com editorial team

HOLLAND: EVs without cleaner electricity power missing the point - study

A new study entitled *Green Power for Electric Cars* claims that electric car use must be backed by clean energy production and a change in legislation in order to achieve zero emissions, reports The Green Car Website.

Research carried out by Dutch consultancy CE Delft concludes that without the decarbonisation of electricity production, electric cars will not truly be 'zero emission' vehicles, and that without a change in EU law they could still be indirectly responsible for a rise in greenhouse gas emissions.

The argument centres around existing EU legislation on car emissions that allows manufacturers to use sales of electric vehicles to offset the continued production of gas-guzzling cars, with 3.5 high-emitting cars permitted for every electric car sold.

The study claims that increasing sales of electric cars to 10% of the total could lead to a 20% increase in both oil consumption and CO_2 emissions in the EU car sector.

Source: just–auto.com editorial team

US: Kia to introduce hybrid this year

Kia will have its first hybrid on sale in the US before the end of the year, the company's director of communications, Alex Fedorak, told reporters at the Chicago motor show.

"It will be available to consumers not just fleets," he said during a preview of the Ray hybrid concept. Fedorak said that he didn't have all the details and was unable to say how closely the production hybrid resembled the concept, according to news agency reports.

The sleek, aerodynamic Ray concept car features a plug-in hybrid powertrain developed with Kia's sister company Hyundai and is designed to help polish the company's green credentials, reporters were told.

"Being green doesn't have to be an obvious statement anymore," said Peter Schreyer, the chief design officer for Kia's US unit.

"The Kia Ray exemplifies a viable blend of modern, eco-minded features for today's environmentally-conscious consumers."

The Ray was designed for maximum efficiency, using clean, flush surfaces which end in a slightly high deck lid for reduced drag.

Touch-screen controls, drive-by-wire steering, 'cool-glazing' solar glass and a lithium-polymer battery hint at the technology in Kia's future.

The Ray's electric motor has a range of more than 50 miles (80km) with a single charge and fuel economy of more than 202mpg and a total range of 746 miles.

Source: just–auto.com editorial team

Lotus hybrid power for the PROTON Concept

The PROTON Concept car, to be unveiled at the Geneva Motor Show, showcases an advanced series hybrid drivetrain, designed and developed by Lotus Engineering.

Lotus Engineering, the world-renowned automotive consultancy division of Lotus Cars Limited announces its latest series hybrid vehicle technology application in the PROTON Concept, which will be unveiled at the 80th International Geneva Motor Show. The complete hybrid drivetrain in the PROTON Concept city car has been developed by Lotus Engineering and it includes the Lotus Range Extender engine, designed specifically for series hybrid vehicles.

The PROTON Concept, a plug-in series hybrid city car, has been styled by Italdesign and will be unveiled on the Italdesign stand at the Geneva Motor Show. Lotus Engineering has designed and integrated the complete drivetrain, including the electrical drive system with single-speed transmission, which delivers low emissions, optimised performance and acceptable electric-only operating range for city use. For longer journeys, when the battery charge level falls, the 3-cylinder, 1.2 litre Lotus Range Extender engine is used to replenish the charge in the battery and provide electrical power for the drive motors. The battery can also be recharged via an AC mains domestic outlet to achieve initial electric-only operation.

Dr Robert Hentschel, Director of Lotus Engineering said: “The hybrid drivetrain of the PROTON Concept is another example of Lotus Engineering’s expertise in electrical and electronic systems and efficient performance engines. The high efficiency Lotus Range Extender engine, which we unveiled to great acclaim at the IAA Frankfurt Motor Show last year is perfectly suited for the advanced series hybrid we have created for the PROTON Concept city car. It is an exciting example of the diverse range of highly efficient total propulsion systems that Lotus Engineering continues to develop for its partners and clients.”

PROTON Holdings Berhad Group Managing Director, Dato’ Haji Syed Zainal Abidin Syed Mohd Tahir said, “Our collaboration with Lotus and Italdesign on progressive technology and design will further propel our competitiveness in the world market. Through this association, we strive to acquire and jointly develop new knowledge, skills and technologies that will ultimately benefit our customers.”

Source: Group Lotus

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Lotus Evora Cup

Lotus Motorsport announced the Evora Cup race car together with an innovative European points based race series for 2010. The race car made its first public appearance at the Autosport International racing car show in Birmingham, UK in January 2010.

The Lotus Evora road car incorporates many race car elements to give it incredible handling and performance. The Evora has a mid-engine layout, high-tech, super-stiff extruded and bonded aluminium chassis and double wishbone suspension all round. These elements mean that it is a relatively easy progression from the production car to a competitive race car.

The Evora Cup race car has been developed by Lotus Motorsport and is designed to offer a level of performance that would make it competitive in GT4 racing. The race car will be eligible to compete in a number of different national and international series, with options for endurance racing and sprint racing.

The Evora Cup show car is finished in Epsom Green with a Solar Yellow stripe down the centre. It is an evocative sports car that will offer a great platform to race in high-level motor sport.

At the heart of the Evora Cup race car is a new 4-litre V6 race engine that boasts more than 400PS and a dry sump system for the high cornering forces encountered during racing. The mid-mounted engine is mated to a Cima six-speed sequential paddle shift dog gearbox, which is designed for international motor sport.

The efficient Evora body has received a Dallara developed aero package, which includes a number of updated carbon fibre parts and significantly improves performance for racing applications, giving greater downforce and improved cooling.

'Performance through light weight' is a Lotus philosophy and the Evora Cup race car has been pared down to less than 1200kg, which translates into a reduction of more than 200kgs over the production car. This weight saving has been achieved by using high-performance parts and materials and deleting parts not required for motor sport

The Evora Cup race car will come with adjustable motor sport dampers and six piston front brake callipers, with two-piece aluminium belled brake discs. The car has an electrical cut-off, fire extinguisher, traction control and is designed to have all the relevant FIA compatible motor sport equipment to race.

The 2010 Evora Cup series will be a European event with points initially being awarded to competitors for entering races, with the points values awarded relative to Evora finishing positions. There will be five points for attending any eligible national race meeting with five points awarded for the first Evora to finish down to one point for the fifth.

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The series will then culminate with two Lotus Festivals, with provisional dates for Donington Park in the UK (16th & 17th October 2010) and the second at Vallelunga in Italy (21st and 22nd November 2010). All the competitors from around Europe will be invited to race at these festivals and there will be double points on offer. The championship winner will be the driver who accrues the most number of points from a maximum of six races over the 2010 season.

Drivers are invited to register their interest at the Lotus Evora Cup website: http://www.lotusevoracup.com

Source: Group Lotus

Lotus Exige S Type 72

The Lotus Exige S Type 72 celebrates the most successful F1 car of all time, the Lotus Type 72 Formula One car, which achieved 20 Grand Prix victories between 1970 and 1975.

The Lotus Type 72 was driven by such Lotus greats as Jochen Rindt, Emerson Fittipaldi, Ronnie Peterson and Jacky Ickx and won three Formula One Constructors' Championships (1970, 1972 and 1973) and two Drivers' World Championships (the first being won by Jochen Rindt in 1970 and the second by Emerson Fittipaldi in 1972).

The colour scheme of the Exige S Type 72 commemorates the famous and easily recognisable black and gold Lotus Type 72 livery and is finished by the same sign writer who painted racing cars for Team Lotus.

The 935kg Exige S Type 72 sprints to 60mph in just 4.5 seconds and to 100 km/h in 4.7 seconds, before reaching a top speed of 145mph, 233km/h. The Exige S Type 72 also offers class leading fuel economy and emissions, with fuel economy of 6.5 litres/100km (43.5mpg) on the Extra Urban Cycle and CO_2 emissions of 199g/km.

The Exige S Type 72 is a powerful supercharged mid-engined sportscar that is equally at home on the racetrack or open road. The intercooled engine has VVTL-i technology, ensuring impressive performance all the way to the rev limiter at 8500rpm.

The Sport Pack comes as standard on the Exige S Type 72 which has a bespoke high-quality interior, including black micro-fibre ProBax sports seats with gold stitching. Each car comes with a special build plate commemorating one of the F1 car's 20 Grand Prix victories. The exterior of the Exige S Type 72 features unique black and gold light weight wheels and is finished with hand-painted gold Type 72 and Exige S logos, (the Sport Pack also includes a T45 steel main roll hoop, Lotus Traction Control, twin oil coolers and an adjustable front anti-roll bar).

All Lotus cars offer outstanding handling and performance and the Exige is no exception,

offering excellent dynamics and great driver involvement. Lotus ride and handling gives an inspiring driving experience and the mid-engined layout of the Lotus Exige S Type 72 offers fantastic balance and agility.

The Type 72 was a very significant car for Team Lotus and indeed for the world of F1. It was a revolutionary design that pioneered the use of side mounted radiators to achieve its distinctive 'wedge' profile, which delivered a significant aerodynamic advantage. Furthermore, by minimising unsprung weight and using a torsion bar, rising rate suspension, tyre performance was excellent. The Lotus Type 72 design was so advanced that it was competitive for an extraordinary six years.

To commemorate the impressive number of Grand Prix wins the Type 72 achieved, Lotus will be producing 20 of this special edition for the UK, a further 20 cars for mainland Europe and there will be a limited run of cars in Japan and selected markets around the world.

Source: Group Lotus

Senior management changes at Lotus

Dr Robert Hentschel

Paul Newsome

The New Year has seen a number of changes in the senior management structure at Lotus, with new faces arriving to continue the success of the group. These changes see CEO Dany Bahar strengthen his executive team in order to take the Lotus brand to the next phase of its evolution and realise his ambitious plans for 2010 and beyond.

The first appointment sees Dr Robert Hentschel join as Director of Lotus Engineering at a time when the automotive consultancy recently announced the fourth consecutive year of growth in new orders for global third-party consultancy work. Dr Hentschel's primary role will be to lead the expansion of this business and to further develop its position of technology leadership in lightweight architectures, driving dynamics, efficient performance and electrical and electronics integration.

Dr Hentschel will have full responsibility for Lotus Engineering worldwide, reporting to Dany Bahar. Dr Hentschel brings a wealth of experience from the automotive industry and engineering services sector, most recently from positions at EDAG as Chief Operating Officer for North American operations and previously as Head of the Electrical/Electronics Business Unit.

Paul Newsome, previously Managing Director of Lotus Engineering, takes up a new role as Director of Product Engineering for Lotus Cars responsible for the delivery of all future cars in an expanding product line-up. Newsome moves to Lotus Cars as Roger Becker, Lotus' Director of Vehicle Engineering retires after a long and distinguished career of 44 years with the company. Becker, 64, joined Lotus in 1966, working on the Elan assembly line at Cheshunt, but his natural driving and engineering skills came to the attention of Lotus founder Colin Chapman and Becker was quickly moved to the vehicle development team where he worked directly with Mike Kimberley (former Lotus CEO) on the Lotus Europa Twin Cam – his first Lotus car development project.

During his career at Lotus, Becker has been responsible for the development of every Lotus car, including the legendary Esprit, Excel, Elan, Elise, Exige and the new critically acclaimed Lotus Evora. Becker has helped to maintain the philosophies laid down by Colin Chapman and has ensured that the essence of Lotus is instilled in all new Lotus cars. He also has imparted his chassis engineering knowledge and development skills to many of the world's major automotive manufacturers in support of Lotus' consultancy engineering business.

The new man responsible for all design activities for Lotus Cars and Lotus Engineering is Donato Coco, Director of Design for Group Lotus. Coco was previously Director of Design and Development at Ferrari, where he worked on the Ferrari F430 Scuderia coupé and Spider 16M, Ferrari California, 599XX and the F458 Italia. Prior to Ferrari, Coco worked for Automobiles Citroën rising to the position of Chief Designer and was responsible for, amongst others, the

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Roger Becker

Xsara, Picasso, C3, C3 Pluriel, C2, C1, ZX Paris Dakar and the Xsara WRC. Head of Lotus Design, Russell Carr will continue to work on both Lotus products and third-party design work, an area which is growing rapidly especially in the emerging Asian markets.

Finally, Andreas Prillmann joins Lotus as Chief Commercial Officer responsible for Sales, Marketing and After-sales functions. Andreas comes to Lotus from Ferrari where he held the position of Director of Business Development, a role that involved the reorganisation of the worldwide business model and dealer development.

Prior to Ferrari, Prillmann enjoyed roles at Aston Martin, Porsche and General Motors. Specialising in the management of sales, after-sales, the dealer network, marketing and PR activities for both brands and products, he brings to Lotus a wealth of skill and experience.

Source: Group Lotus


Donato Coco


Andreas Prillmann

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The new Lotus Elise probably has the lowest CO_2 for its performance for any gasoline high performance sportscar in the world

The Lotus Elise revolutionised the sportscar market 14 years ago when the small lightweight agile two-seat mid engine sportscar was introduced.

By ensuring that the Elise stuck rigidly to Lotus' core values of performance through light weight, the Elise was able to produce supercar performance with city car economy.

Making its debut at the 80th International Geneva Motorshow, the 2011 model year Lotus Elise introduces a number of changes and improvements to maintain its class leading position.

For the 2011 model year, the Elise range will consist of the following variants:

- Lotus Elise – 136PS, less than 155g of CO_2/km – new 1.6 litre engine*
- Lotus Elise R - 192PS, 196g of CO_2/km - 1.8 litre engine
- Lotus Elise SC – 220PS, 199g of CO_2/km - 1.8 litre supercharged engine

Key changes and improvements to the whole of the 2011 model year Elise range:

- new evolution body design incorporating new front clamshell, rear bumper and engine cover;
- new all-in-one integrated headlights including LED day light running lights and LED direction indicators;
- improved aerodynamics with a reduction in Cd by 4%, resulting in better fuel economy;
- new cast and forged wheels;
- vehicle warranty increased from two years to three years and 36,000 miles.

Additional changes for the 2011 model year entry level Lotus Elise:

- new high technology 1ZR-FAE 1.6 litre engine with Valvematic and Dual VVT-I technology to optimise the performance and efficiency of the engine;
- less than 155g of CO_2 per km (an improvement of over 13% compared to the 2010 Elise S)*;
- combined fuel consumption 6.14 litres/100km (46mpg)*;
- new six-speed close ratio gearbox;
- cruise control available as part of the Touring pack.

The body – an evolution

The new 2011 model year Elise range is on sale now and will be in showrooms from April 2010. The body of the new 2011 model year Elise is an evolution of the iconic Elise design, retaining the character and style, while offering a more planted, purposeful stance and a pure, contemporary look that links it to the Evora. As with all Lotus products

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the design is an exciting blend of dramatic style and functional efficiency

The new Elise body has a fresh sculptured front, including a new bumper, front clam and access panel that combine to give the Elise a wider look with more road presence.

At the rear of the car the new engine has been encased by a distinctive 'twin-spine' engine cover whilst lower down a more aggressive diffuser is tightly wrapped by an elegant new bumper design that now includes the rear licence plate.

New headlamp units with distinctively sculptured LED lighting guides (incorporating daytime running lamps and direction indicators) give a contemporary twist to this classic design. Elsewhere, the signature, Lotus 'mouth' and familiar sculptured forms have been sensitively refined to give a crisper, more dynamic look. The repositioning of lamp functions has enabled the creation of broad clean surface between the fenders which combines with sleek corner intakes and prominent splitter detail to give a broader, more planted stance.

The theme of purity is carried through to the cooling apertures that are efficiently finished with a new lightweight aluminium mesh that gives the car a classically sporting character.

The rear boot is now opened from the cockpit rather than via a separate key operation. The high-quality feel of the Elise is continued throughout the car with the Elise graphic incorporated into the new side LED direction indicators, like those on the Evora.

The driving position, from the perfectly positioned pedals and steering wheel, to the comfortable and supportive seats with ProBax technology means that, like all Lotus cars, the driver becomes part of the car rather than being just a passenger.

With the sleek new body the aerodynamics have improved giving a reduction in the coefficient of drag of 4%.

Finally, a choice of two beautiful, lightweight wheel designs are available; an incredibly light forged wheel and a new cast wheel completes the picture for this sensitive update of a Lotus Icon.

Additional changes to the 2011 model year Lotus Elise

The new 2011 model year Elise has a number of additional changes and improvements, with the installation of a new advanced 1.6 litre Valvematic engine meeting EURO 5 regulations. This new engine is 200cc smaller than the outgoing Elise S model and produces similar power (136 PS, 100kW, 134hp at 6800rpm) with maximum torque of 160Nm, 118lbft at 4400rpm, but offers a significant improvement to fuel economy of over 23%, to 6.14 litres/100km (46mpg) and a reduction in CO_2 emission by more than 13%*. This provides the new Lotus Elise with the lowest CO_2 per performance for any gasoline high performance sportscar in the world. This high technology engine is mated to a new six-speed manual gearbox, providing closer and more performance orientated ratios than the outgoing 5 speed box.

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The 1.6 litre engine is controlled via the bespoke Lotus T6 engine management system. Cruise control is available on the Elise for the first time with the controls present on a stalk located to the left of the steering column.

New cast wheels have been designed specifically for the Elise and the new optional forged wheels weigh just 29.26kg per set, 2.14kg lighter than a set of lightweight cast versions. Both are available in silver or black colour.

Dany Bahar, Chief Executive of Group Lotus said: “The Lotus Elise revolutionised the sportscar when it was launched 14 years ago and now the Lotus Elise has become greener, giving drivers access to class leading performance with less guilt.”

Donato Coco, Director of Design said: “The Elise is an iconic sportscar and it was important that we did not complicate its design, so we made the car more pure in its look, improved the aerodynamics, and gave it a more contemporary look with high-quality detailing.”

Source: Group Lotus

*The Lotus Elise is currently undergoing EC Whole Vehicle Type Approval and official fuel consumption and CO_2 emissions figures, plus performance figures are not yet available. The official figures for fuel consumption and CO_2 emissions and performance will be published on Group Lotus plc's web site as soon as they become available (www.grouplotus.com) or may be obtained from the PR Department, Lotus Cars Limited, Potash Lane, Hethel, Norfolk, NR14 8EZ, UK.

Performance

Lotus Elise*

0 - 60mph	6.0 seconds
0 - 100km/h	6.7 seconds
Maximum speed	200km/h (124mph)

Lotus Elise R

0 - 60mph	5.1 seconds
0 - 100km/h	5.4 seconds
Maximum speed	222km/h (138mph)

Lotus Elise SC

0 - 60mph	4.3 seconds
0 - 100km/h	4.6 seconds
Maximum speed	233km/h (145mph)

Source: Lotus Cars

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The new proposed EU and US emissions regulations from a small-volume manufacture perspective

Simon Wood, Technical Advisor for Group Lotus, has been leading Lotus's activity with the European and US governments on CO_2 and greenhouse gas legislation. He takes a look at what the regulations will say and their impact on Lotus and small-volume manufacturers

During the last 12-18 months there has been substantial activity throughout the automotive industry in influencing and understanding the impact of the new CO_2 reduction regulations applied to vehicles from 2012 in both US and EU markets. It has been an interesting, at times frustrating, and a worrying time to be a small-volume vehicle manufacturer (SVM). I'm sure the same comments can be applied to major manufactures; we just see the world from a different perspective.

The European Union position

A regulation for the introduction of compulsory CO_2 levels was approved by the EU member states and the European Parliament in late 2008. The regulation[1] entered into force in April 2009 with implementation set for 1 January 2012. What was a voluntary objective for CO_2 reductions will become a mandatory target because of the claimed failure of the automotive industry to meet previously agreed reductions.

For 2012, the limit is set such that the average of all cars retailed in the EU markets should be 130g/km when measured on the standard New European Drive Cycle (NEDC) of 11km duration. The regulation allows, in part, for the recognition that larger cars will emit greater levels of CO_2. There has been much debate, lobbying and persuasion from many different parties, and indeed countries, protecting their interests as to how this will work, but the Commission has decided upon the target of 130g/km applying to a vehicle of average weight in 2007 of 1372kg. A linear relationship defined by the formula CO_2 g/km =130+0.0457(mass kg-1372kg) adapts the target for vehicles of other weights. The heavier the car the more you may pollute and if a manufacturers average exceeds the target a fine will be applied reaching a maximum of EUR95 per vehicle for every g/km over the limit by 2016. This is a harsh penalty and substantially in excess of the price per tonne paid by companies able to participate in the EU's Carbon Trading Scheme (ETS). When challenged on this difference, the EU decreed that it is the price the auto industry has to pay for its previous desire to be exempt from the scheme and its lack of compliance with the voluntary CO_2 targets.

The EU CO_2 regulation applies to all M1 classification vehicles which are defined as passenger carrying vehicles of up to 8 seats plus driver. Although not formally exempt yet, the legislation cannot be applied to single type approval vehicles as there is no CO_2 result recorded on the UK's Individual Vehicle Approval (IVA) certificates for these vehicles.

The method of application of the regulation is a fiscal penalty targeted to encourage each manufacturer to reduce its overall fleet average of CO_2 emissions across the entire model range. Manufactures with a wide range of product types may therefore offset heavy polluting vehicles against clean ones to achieve their average. This will require careful future product planning and assumes some ability to encourage the market to buy the cars in the specific volumes needed to balance the emissions. This is particularly difficult for manufacturers with a limited or narrow product range.

In recognition of these difficulties the high-volume manufactures have petitioned and been granted an exemption for a proportion of their fleet, giving time to introduce models with lower CO_2 output.

Niche volume manufacturers, where niche is defined as a narrow product range and volumes less than 300,000 retails in EU per annum have been granted a unique position where they have to show a 25% reduction in CO_2 from their 2007 figures (the high-volume manufactures have to show approximately a 14% reduction over this same period to achieve 130g/km) but there is no defined CO_2 target. It is instead a manufacturer-specific target based upon data from 2007. This was the last year that full year sales and CO_2 data were available when the legislation was being drafted.

Small-volume manufacturers are expected to be different again with an ability to request a derogation from the target with a requirement to show a reduced CO_2 figure by 2016. This derogation is based upon individual manufacturers' economic and technical situations recognising that many of the SVMs use engines from larger manufactures which they have little control over, in addition to such a small product mix, if any, that it is not possible to 'fleet average'. Small-volume in this case refers to volumes of less that 10,000 sales per annum and it is the category in which Lotus Cars falls.

The Commission see these clauses as 'good lawmaking' having avoided a one-size-fits-all approach whilst delivering the desired CO_2 reduction result. However, the process is not yet complete. Having passed into statute, the regulation now needs a process to implement the decision. Following the adoption of the regulation, the European Commission has been developing detailed guidelines for the implementation of the derogation applicable to small-volume car manufacturers. These guidelines may not alter the spirit of the basic regulation, only define its application in detail. During the process of drafting the guidelines – a process known as comitology - the European Commission has sought input from both member states and interested stakeholders. The guidelines are currently being finalised and expected to be adopted in April 2009, followed by a three-month period where the European Parliament can veto the text. If unchallenged, the Commission's proposal becomes law. The end, like it or not, is in sight

A couple of points have surprised me during the passage of this law from the perspective of an individual who until recently had only limited exposure to Brussels. Firstly, the process is very democratic, attempting to achieve consensus at all points and this obviously requires countries and industrial associations to move their stance during these complex negotiations. Secondly, the staff available to the Commission to complete this work is very limited in capacity but high in capability. Finally, I had originally, I have to confess here, assumed that lobbyists were a scourge on society. Actually I've learnt that they perform a valuable job in assisting in informing MEPs of issues and views in what appeared an efficient and effective manner.

The US position - similar but different

- different test cycles – the proposal is to continue to utilise the existing 55% City and 45% Highway 'combined' test procedure;
- a CO_2 target that decreases year on year;
- an allowance for different size vehicles based upon their footprint (track x wheelbase) rather that mass;
- again a linear relationship of CO_2 with footprint but with a 'flat' section at each end of the curve;
- making 'illegal' the sale of vehicles that do not comply;
- a CO_2 credit trading scheme amongst manufacturers;
- substantial GHG incentive for flex fuel vehicles;
- temporary 25% allowance for manufacturers who sold less than 400,000 vehicles in the US in 2009 and an exemption for independent "small entities" (manufacturers with less than 1000 staff).

The Environmental Protection Agency (EPA) and National Highways Traffic Safety Administration (NHTSA), working together will be implementing a Greenhouse Gas (GHG) regulation in the same time frame as the EU CO_2 legislation. The US regulation is still only proposed but some of the principal differences are:

Small-volume manufacturers (i.e. those that are independent with less than 15,000 US sales per year) have made a proposal to the EPA to apply multipliers to the proposed standards dependent upon the SVM's annual US sales.

The new proposed EU and US emissions regulations from a small-volume manufacture perspective

As with the EU situation, this is again a complex piece of proposed legislation which has completed its consultation stage (during which the Agency requests formal written input on the proposal), and is now in re-drafting taking into account those inputs. We would expect to see the final proposal late March/April 2010.

EPA has devolved powers and is the law-making body itself without a requirement to recommend to the Senate. However, in practice, for legislation of this magnitude and impact, political views will be sought in Washington DC.

The EPA technical staff are mainly based at Ann Arbor, MI, where the physical conformity testing centre is based. These teams will draft the final proposal and options which will be passed to EPA Administration in Washington DC for a final decision. Currently the targets proposed require approximately a 30% CO_2 reduction (from 2008 data) to a target in 2016 of 224gm/mile for a nominal footprint vehicle (see Figure 1). This relates to a fuel consumption figure of approximately 39USmpg, a significant improvement from today's figures.

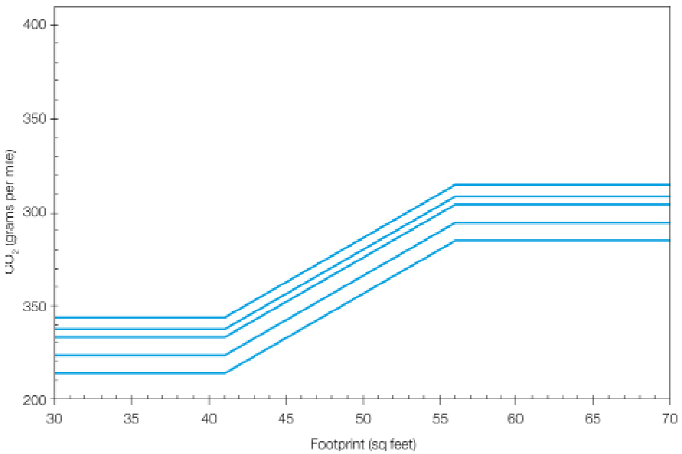


Figure 1 - US CO_2 (g/mi) Car Standard Curves

Unfortunately the differences in the drive cycles result in technologies that work to a benefit in the EU but do not necessarily deliver improvements on the US drive cycle. Stop-start technology is a good example here. We can expect it to become almost standard in the EU because of the impact it has during the drive cycle but with little penetration in US markets due to the very short periods of engine idle within the test cycle and the domination of automatic transmissions.

Both pieces of legislation should be decided by mid 2010; Canada looks like it will be next and is expected to broadly follow the US example.

Impact on vehicles and manufacturers

The implication of this legislation will be a rapid move to smaller, lighter and more fuel-efficient cars as part of manufacturers fleets in order to bring down the fleet average GHG emissions. Evidence suggests a substantial number of hybrid vehicles will be introduced before 2015 in order to further reduce the average CO_2 before the increase in penalty is applied from 2016. Battery electric vehicles will remain in the domain of a few specialist manufactures or those who have a large market share in an urban environment. Achieving the necessary product volume mix will be critical which I could imagine may see some surprising discounting from high volume manufacturers to influence the retail market in later years.

Lotus Cars finds itself in a strong position here with our products already at or near the top for low CO_2 output within our product categories as a result of

our philosophy of performance through light weight. Furthermore, the introduction of the new legislation will provide opportunities for Lotus Engineering with the application of our experience in light-weight structures, electric and hybrid vehicles and clean efficient combustion.

[1.] Regulation No 443/2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles, available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009R0443:EN:NOT

Source: Simon Wood, Lotus Engineering

Richard Parry-Jones is best known for his time as a leading automotive engineering leader at Ford. Until his retirement from Ford at the end of 2007, he spent nearly ten years as Group Vice-President in charge of R&D for all of Ford and its subsidiary companies worldwide, leading a staff of 30,000 professionals in a network spanning 15 countries.

The much lauded 1998 Mark 1 Ford Focus emerged under his guidance. He now runs his own technology consulting company and provides policy advice to Governments. He chairs the UK government's 'Automotive Council'. *just-auto* editor Dave Leggett recently caught up with him.

This is the first part of 2 part interview that will conclude in the next issue of proActive

DL: How are you spending your time these days?

RP-J: In the past two years I have stopped working full-time, which was all part of my plan, and I now spend just over half of my time working. There are three main areas where I am working: one is the public sector; the second is non-executive directorships; and the third is my technology consulting company.

The public sector work is mostly developing policy advice for governments – both the UK government in London and the Welsh Assembly Government in Cardiff. The portfolios I cover are manufacturing and specifically the development of the automotive industry in the UK, energy policy, economic policy and transport policy. I am essentially a policy adviser in those areas and I do find the work very interesting.

The other work I do in the public sector is with universities. I have been a visiting professor in the department of automotive and aeronautical engineering at Loughborough University for a number of years. I am continuing in that role, providing occasional lectures, tutorials and also advice on course development. I am also a member of the advisory council for Warwick Business School and also the advisory council for the Liverpool John Moores University (working on a programme called World of Work – WOW – making undergraduates more workplace-savvy and therefore employable).

I have also just joined the council of Bangor University in North Wales and I am gradually increasing my involvement with them (I was born in Bangor and I have moved back to live in the area).

Non-executive directorships include being a member of the board of GKN plc. I am also a member of the supervisory board at a German company called Odersun, which makes clean technology devices.

I also set up my own consulting company when I left Ford, so that's been running for about two years now. I have a growing client list and turnover. Interestingly enough, I have been able to expand my client portfolio well beyond the automotive sector to general engineering and technology consulting – for example, advising the investment community on the attractiveness of new technology innovations. There is obviously some consulting with automotive companies, but I have gone as far afield as the energy sector and the civil engineering sectors, working on broader strategic issues that involve the marriage of technology and business.

DL: And how are you filling the half of your time that is not working?

RP-J: I am something of an outdoor sports fanatic. I do sea-kayaking, sailing, jet-boats, mountain biking, motorcycling, backpacking and I'm also still active in motorsports (Fiesta ST rallying). Cooking is also a big passion of mine. So there's plenty to keep me occupied outside of work.

DL: Looking back at your Ford experience, what would you pick out as key developments that you were involved with on the engineering side?

RP-J: A lot happened in the industry over the 38-year period that I was there. Of the things that stand out, probably the biggest was the introduction of digital electronic control. It was zero when I joined the industry but it is utterly pervasive now. It has got to the point now where we carry more lines of code in a car now than in an aircraft and far more than in a PC.

What we have been doing as engineers is to harvest the results of Moore's Law as it applies to microelectronics. This has reduced the cost of processing power to allow us to interfere with hydro-electro and mechanical systems, which are essentially linear, to create desirable non-linearities at relatively low cost. More recently digital electronic control has been used for autonomous closed loop control of many vehicle systems.

I specialised in control in my degree course, so it's interesting that that became extremely useful throughout in my career.

That's probably the biggest single thing but of course there have been massive changes in other areas and two stand out:

The increasing importance of safety and the environmental impact of cars. Both of these things have been driven by the incredible popularity of cars – which have been subject to much improved reliability and affordability. The real cost of motoring has been dropping inexorably over time, despite the best efforts of governments to penalise motorists through punitive taxes.

Reliability has got to the point now where most people don't really worry too much about reliability, in the sense that they used to – there is an industry standard that has been getting steadily better. Cars are much more reliable mechanically and electrically than aircraft and they remain in service now for about 16 years and that number is increasing by a year every four or five years.

So the cost of motoring to the average motorist – who is not a new car buyer – is dropping even faster because of the incredible value for money offered in the used car market.

The big enablers have been the rising productivity and efficiency of the industry. Global competition has driven the cost of motoring down. Reliability has made motoring a preferred choice rather than a risky choice.

That incredible popularity has brought with it challenges of safety and of the environment and the industry's technological response has been impressive.

Under the broad heading of safety we have structure, restraint systems and accident avoidance. Structural innovation has been accompanied by the deployment of very sophisticated restraint devices. Take for example the number of airbags that a car has nowadays. With the Ford Mondeo in 1992, that was the first mass-market car to standardise an airbag on the driver and passenger side. Now, you typically get between six and ten airbags on a modern car as standard. And beyond that, seatbelts have become very innovative. I have worked, for example, on a device that we have just launched in America under the Ford brand called the 'inflatable seatbelt'.

The innovation continues with the increased development of accident avoidance systems, Under the broad heading of 'the environment' we started off with the concern over smog formation which led to the development of the three-way catalytic converter. Then came the more macro concern over possible destruction of forests through acid rain, so further stringency was added to tailpipe emissions regulations. This was followed by concerns over particulates and their effects on respiratory diseases. Now of course, we have the concerns over the most 'non-local' emissions of all – carbon dioxide.

Despite initial reservations, challenges and opposition, the industry has responded spectacularly with some very clever technology each time regulations have been tightened up.

The Ford Mondeo in 1992, that was the first mass-market car to standardise an airbag on the driver and passenger side.

The first three-way catalyst system cost US$145 more than having no tailpipe emissions equipment at all. The latest systems that are on cars in the US emit emissions of CO_2, hydrocarbons and nitrous oxides of less than 1% on what was allowed under the 1973 regulations. And the cost of the system that delivers that degree of improvement is just US$142. I think we sometimes underestimate the power of continuous improvement in terms of innovation. We've got a system that gets rid of 99% of what used to be allowed at no more cost to the consumer.

DL: When you look back at your Ford time, is there any one model that stands out as a game-changer in terms of the product development process leading into the quality of the end-product, driving dynamics, benchmarks and so on?

RP-J: Of all the cars I was involved in the one that absolutely stands out for me is the original Ford Focus. That was in many ways my team's expression of everything they had learned about car design. It changed standards in the class and in adjacent classes. We all felt very pleased with the outcome – it won all the awards going, it was produced and sold all around the world, customers loved it, it became the benchmark for many competitors' engineering teams and it still looks fresh and drives well today.

DL: What factors can you identify that produced that outcome?

RP-J: As always, lots of factors. Ford has a fantastic team of engineers, and the ambitious setting of goals, the engineering process, the culture, the team – and particularly the selection of the team leaders were all important. But crucially, I also had the unwavering support of Senior Management colleagues, who shared by ambition to fundamentally change the type of vehicle that Ford produced – from a company fleet vehicle solution provider to making cars that are much more desirable to look at, to own and to drive.

That car was much more engineering led than finance led.

That doesn't mean that the development process was financially irresponsible – there were clear targets to be met - but the judgements were made by people with deep technical knowledge rather than by people relying on other people's deep technical knowledge. There's a big difference there.

The other thing is to be confident – or even courageous – enough, to set very high standards and not to compromise when the going gets tough.

The differences between a great and just very good are often just a few percent, in terms of measurables. And you have to get everything working 'just right' as opposed to nearly everything working about right.

DL: Are the compromises that might get made in the development process typically about time and particularly the trade-off of time – to get something perfect – and the cost budget?

The control blade rear suspension adopted on the Focus was more expensive than the industry norm of torsion beam axles

RP-J: I think many companies and products suffer from having not pushed hard enough on the product and allowing the incredible pressures of time, budget and compromise to influence too many decisions.

For example, the control blade rear suspension we adopted on the Focus was more expensive than the industry norm of torsion beam axles, and it was more risky, but it was absolutely crucial to giving us a rear suspension with a level of grip and response at the rear that allowed us to do some completely different tuning at the front of the car that created that special feeling when you drove the Focus.

My argument would be that you mustn't become so obsessed with perfection that you forget all about the commercial issues, but you have to get to the point where you know that the engineers can't do any better, as opposed to saying they can't because they are just tired out, or they are worried about budgets or whatever.

You have to be quite strong because the pressures in any organisation are incredible to compromise. I'm just a bit more difficult to persuade to compromise than some other people.

I have been accused of a tendency to spend a bit of extra money, but my response has always been that if you want to raise the revenue outcomes of your products, then you need to invest in a reason for your customers to pay a little bit more. And that can take time in terms of the brand perception and consistently delivering a premium product, so that eventually customers think that it is worth paying a little bit more for a Ford because a Ford cars really are better.

And I believe the Mk 1 Focus had a lasting impact on the way people viewed Ford in Europe and I am very proud of that. By the way, it was a huge team effort on that car. There were more than 800 people directly involved in that car's development, so I don't want to exaggerate my role.

DL: Can you identify other models that you were very happy with, in terms of their development?

RP-J: There were a lot of models I was involved with that I was very pleased with. I was very, very happy with the Land Rover Discovery 3. That was another perception-changing model. The Range Rover at the time was largely engineered by BMW and it did a fantastic job of raising the premium, almost unassailable position of the Range Rover in the market. I think many people thought – after we had acquired Land Rover – that we wouldn't be able to do a job anywhere near as good with our own developed model. But I think we really surprised everybody with how fundamentally brilliant Discovery 3 was.

Land Rover Discovery 3 exceeded perceptions

And I think recently the Jaguar XF has been another very, very good model. I was very pleased with the work that the team did on the XF. Not only is the XF a model that is working to change perceptions of the brand and take Jaguar to a new audience, but the engineering team at Jaguar had been raising their game for some time before that, honing their skills, and I think it came together very well with the XF. It was also the first Jaguar to use a new product development process that I had been developing worldwide and that seemed to work very well.

DL: What do you think went wrong with the X-Type? Was it the execution or the perception that it was sharing parts and platform with the Ford Mondeo?

RP-J: I think the X-Type was actually an extremely good car. The idea of doing a premium car and using some of the parts kit from volume models was not new when we did the X-Type and wasn't unique to Jaguar. It also been tried successfully many times since. The criticism that the X-Type was drawn partly from a set of parts from the higher-volume but rather excellent Mondeo is misplaced – you may as well level the same criticism at Audi for any VW parts they have used. I really don't think that's the issue.

And I think the team executed it pretty well. It handled well, steered well. It was reasonably refined. But I don't think the design craftmanship was quite at the level that was needed at the time, despite the fact that the Halewood plant did a wonderful job with that car.

The X-Type had image problems with some drivers

But I think the real reason why the X-Type didn't take off and earn its way into people's hearts the way we hoped it would, was actually appearance. The design was too conservative. And for a smaller, less expensive and more affordable Jaguar, instead of making it look like an older person's car that you could now buy more cheaply, I think we would have done better by being bolder and more contemporary with the styling. Then it would have appealed to a new audience, rather than the existing audience or an audience that had always hoped to own a Jaguar but never thought they could afford it, but suddenly realised they could.

With the benefit of hindsight a bolder and more modern design could have said, 'Hey, you know what? Jaguar is also a youthful company appealing to youthful people with a contemporary design.' And then I think we would have heard very little of the other criticisms.

DL: And now it's going the other way with bolder designs, like the XF and XJ?

RP-J: Yes, that's right. The X-Type was part of an attempt to grow the company very fast and, as that did not work out economically, then obviously the model for the business has to change, at least for a while, and that's why we're now seeing a heavy emphasis on progressive, bold design, craftsmanship and premium materials along with clever technology.

Bold lines of the XF was a change of direction for Jaguar

Part of the reason why Jaguar was tempted to go down the 'design cloning' route was that the competitive environment at the time showed that was the approach successfully used by companies like Audi, BMW and Mercedes. They all basically had a house style with different sizes of vehicle. Jaguar's approach was actually following the mainstream premium brand trend, so it seemed plausible at the time. The difference was that the audience who had bought in to the Jaguar house style up until that point was a) too small and b) rather mature – if I may use that word.

DL: How do you define 'craftmanship'?

RP-J: It's a lot of things – a combination of design, materials and geometric fit. Many of those things were done very, very well but at that time Audi, and to a lesser extent BMW, were setting the standard. And when you introduce a new model into a new segment and you're trying to break the mould a little bit, it's not good enough to just be as good as the competition, you have to be better to give people a reason to buy you rather than the established choice.

DL: We have already touched on aspects of this, but what do you see as the key principles that produce good cars, from an engineering point of view?

RP-J: The answer to that question can vary according to the market or segment you are aiming at. First and foremost, the car has got to be utterly dependable. It has got to provide good value for money – that doesn't necessarily mean low price; the customer has to feel they are getting a really good deal and it doesn't mean getting a discount. It means being so pleased with the product itself and taking delight in it in various ways, that they feel they have made an excellent purchase. That feeling should not only be driven by novelty, it should be driven by depth, depth of competence.

And the car has to look good. It's either got to look fascinating or interesting, exciting, or it has to look really contemporary, cool. The appearance has to denote quality.

Customers have no means of assessing quality in a technical sense. What they do, and what we all do, is shut the doors, fiddle with trim, ping the mirrors, feel the materials, hit the switches and depending on how solid or flimsy or noisy the car is, they will draw conclusions about some of the things they can't assess, like the wheel bearings, say. The car has to be designed so that it communicates quality visually, aurally and tactilely.

And when you actually open the car door, it has to be inviting. In that it is interesting – you want to find out more. Or it is inviting simply because it looks supremely cosseting, comfortable and convenient – easy to use.

And exactly how you configure all of that has to match your buyer and the segment the car is in.

I always do a test when someone shows me a new car – I open the door and I stand there. I look at it and

I ask myself the question: do I want to get inside and find out more? If the answer is 'no' I'll stop the review at that point and I'll say, 'I will get inside in a minute, but I want to tell you we need to do more here, here and here, because at the moment I, as a potential customer, don't want to get inside, it's not interesting enough.'

And once you are inside, then we're into the ergonomics, seating position, sense of space and the feeling of connection between you and the car.

After that, we are on to my '50-metre test'. We should be able to tell after driving the car at low-speed for 50 metres whether we have a brilliant car or just a good car. And that is all about how the controls respond and communicate to you what the car is doing.

DL: Were people doing anything like that 50-metre test before you suggested it?

RP-J: I am not sure anyone in the industry was doing it. People tend to see a prototype, jump into it as small horns start growing out of their heads and they drive immediately flat-out.

I learned a lot about this from Jackie Stewart – I didn't wake up one morning with a brainstorm. I was lucky enough to work closely with him in the very early 1990s and we spent quite a lot of time together in cars. I learned a lot about driving from him, as you would expect, but I also learned a lot about understanding vehicles.

One of the key things he taught me was: don't rush it, take it easy, spend time at the beginning. Don't even drive away for 20 minutes while you are understanding the car from a static perspective.

And then when you do drive away, do not allow your enthusiasm or sense of urgency to get the better of you. Gradually build up your speed, and treat the controls very gently. One of the little things that makes a car good is the question of freeplay when you press the throttle pedal and before the car starts to move. Sometimes that freeplay might be only 5mm but that is 5mm of backlash that is a barrier to you and your car having perfect harmony.

If you are not preparing yourself mentally to understand whether that 5mm exists or not and you just get in the car and floor the pedal on your first drive, you will never find that problem.

But you will find it in the first 50 metres – are the controls nicely weighted, are they linearly progressive, lacking in lash, are they communicating, are they helping my driving? Or are they giving me a series of challenges?

DL: Do you think that kind of approach has become an industry standard now?

RP-J: I don't know about other companies, but I know that at Ford it is still a term and practice that is used.

DL: I guess we know that bad cars still get produced, so for all the improvements to quality industry-wide that you mentioned earlier, some companies are better at producing high quality cars than others.

RP-J: And it could be of course, that in some companies the engineers are doing things like the 50-metre test, but there are other pressures that mean perhaps these things are not being paid

attention to in the decision making process. It's about detecting problems, developing a fix and following through, even if it is hard work and more work. There are many possible causes for that particular failure mode.

This interview will conclude in the next issue of ProActive

Source: just–auto.com editorial team

Could upsizing be the new downsizing?

Engine downsizing has become an industry-wide trend in the pursuit of improved fuel economy from automotive engines, particularly in the case of spark-ignition (SI) engines. The reason for this is that it provides a practical way of reducing the effect of throttling loss in the drive cycle, this being the main disadvantage of the 4-stroke SI engine at part load and a consequence of the double use of the engine combustion chamber as the scavenge pump for the cycle during alternate revolutions of the crankshaft. In SI engines, downsizing is typically achieved by employing a small, pressure-charged engine in place of a large, naturally-aspirated one, thus ensuring that for the area of the speed-load map in which the engine operates in the drive cycle, the throttle is wider-open for more of the time and the work employed per cycle in pulling the charge air past the throttle is therefore reduced. Pressure charging is then employed to enable the engine to produce the power of the original large NA unit.

Lotus 3-cylinder, 1.5 litre downsized SABRE engine concept

The reason that downsizing has been widely embraced by the industry is that despite the extra technologies required to mitigate the disadvantages of the approach (principally knock and abnormal combustion at the high loads necessary to make the same absolute power as a large engine with a small, boosted one), the exhaust gas after-treatment system is relatively cheap – a conventional three-way catalyst can be used. While mechanically-variable valve trains such as Valvetronic reduce throttling loss directly through manipulation of the intake valve closing point, such systems are expensive to implement even though they do retain the benefit of cheap and robust after-treatment systems. The final engine-based (i.e. non-hybrid) approach to reducing throttling loss in SI engines, stratified operation, not only generally demands more expensive fuel injection and control equipment, it comes with a significant penalty in the form of the need for dedicated after-treatment systems for the control of oxides of nitrogen in an overall-lean exhaust gas stream. While stratified combustion can offer significant benefits, it is only found in premium vehicles at present, such is the increase in total system cost relative to a downsized-stoichiometric combustion approach, the latter of which also additionally improves the mechanical efficiency of the engine at high load.

As mentioned, the 4-stroke (or Otto) cycle suffers throttling loss because the working chamber alternately functions as engine (during the compression and

expansion strokes) and scavenge pump (during the exhaust and intake strokes). The high compression ratio advantageous to thermodynamic efficiency in the engine portion of the cycle is extremely disadvantageous during the scavenging cycle; what is now the pump (rather than an expander) has to pull a partial vacuum through what is a needlessly large expansion ratio. In effect this means that as one increases the compression ratio of a 4-stroke SI engine, the throttling losses increase. Generally the effect of this is overcome by the improved thermal efficiency of the engine portion of the cycle, but returns start to diminish at full load operation at around 15:1 compression ratio (before which point combustion limitation in the form of knock is usually met with conventional gasoline fuels); this is despite the air standard cycle efficiency increasing with compression ratio – see Figure 1.

The ideal would perhaps be to divorce the engine function part of the cycle from the scavenge pump function; if this were done the engine component of the cycle would be immune to the disadvantage of increasing compression ratio increasing part-load losses, and the scavenge pump component could operate at a much lower expansion ratio. Superficially, such an approach would appear obviously-desirable but extremely difficult to implement.

Except that it isn't. What is described in the previous paragraph is the 2-stroke operating cycle and, it is contended, it is far better suited to the demands of part-load operation than the 4-stroke cycle. The issues of emissions control in 2-stroke engines will be returned to below, but it should also be noted that in general the mechanical efficiency of 2-stroke engines is 3-5% higher than 4-strokes, and the thermal losses are lower, too. From a design perspective, the degree of over-engineering of the connecting rod and combustion chamber is reduced since those components handle the pressures of combustion twice as often as in a 4-stroke, so material utilisation is better, too. What the 4-stroke engine does have in its favour, though, is manufacturing infrastructure and the sort of long-term development that can only come from becoming the dominant technology in a cost-effective marketplace.

The SI 4-stroke engine is now under significant threat from many quarters, however. This is a result

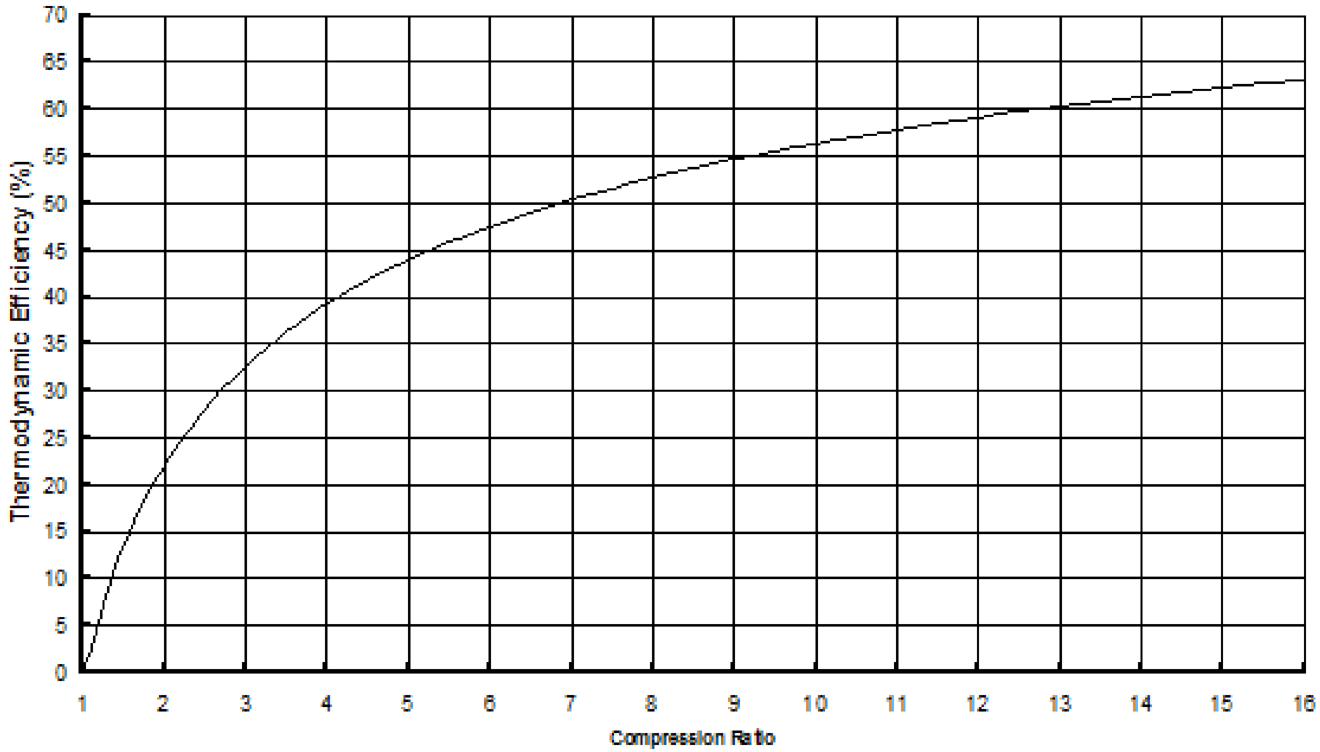


Fig. 1: Simple air standard cycle efficiency calculation for the Otto cycle (calculated with constant ratio of specific heats of 1.36 assumed across the entire operating cycle)

of the fact that it is a highly-evolved concept and consequently further advances are hard-fought. Because of this, other markedly different concepts are being championed, such as full battery-electric vehicles, plug-in hybrids and fuel cells; all are more costly technologies with varying demands on infrastructure and, importantly for the OEMs, the manufacturing infrastructure that they have built up. Increased downsizing will undoubtedly help to improve 4-stroke efficiency within the existing manufacturing infrastructure, but it is contended that the 2-stroke engine is a reasonable and pragmatic next step in engine evolution, because it does not mean stranding all of the manufacturing assets already in existence, and can still be made at a price people can afford to pay because it does not contain expensive materials.

However, in the automotive arena, prejudice against the 2-stroke engine is very strong. In the broader engine market, however, it is the engine of choice where either high power-to-weight or maximum fuel efficiency is required; so-called 'cathedral' 2-stroke

Lotus Omnivore concept single-cylinder monoblock

diesel engines are the most thermally-efficient propulsion engines available (at least at sea level). This fact about the engine market needs to be borne in mind and then the question asked, 'Why has the automotive community failed to master the 2-stroke engine when so many other areas of engineering have?'

If this were possible, many advantages over the 4-stroke could be realised. Because it combusts twice as often, a 2-stroke engine of the same swept volume would require half the BMEP of a 4-stroke to make the same power at the same revs; this has important ramifications for fuel octane appetite in SI combustion. More importantly, because of the practical elimination of throttling loss, there is no need to pursue downsizing as a fuel consumption improvement technology. In fact, engines could be upsized without fear of throttling loss were this considered a desirable technology direction to take. This will be returned to later.

Perhaps one of the most exciting possibilities is that, while many types of 2-stroke engine configurations exist, some of them permit simple and readily-controllable adjustment of compression ratio in a manner impossible to implement (in terms of range and simplicity) in a 4-stroke engine. At the same time, this can be done with no effect on throttling loss.

This is what the Lotus Omnivore concept does. This is a loop-scavenged engine operating on the Day 2-stroke cycle, i.e. it has piston-controlled transfer and exhaust ports at the base of the cylinder, freeing up the cylinder head area completely. It has external scavenging for reduced oil carry over and increased architectural similarity to existing 4-stroke engines. The fact that the cylinder head is now devoid of valves and ports permits the ready adoption of a simple VCR mechanism, which in this engine yields a compression ratio adjustment range of 10 to 40:1, and it is this that allows the final problem of 2-stroke emissions to be fully addressed. Such a wide range of compression ratio adjustment permits super-wide-range HCCI to be used, where compression of the charge alone is used to ignite the fuel; for several reasons this range is significantly larger than can be achieved with VCR in a 4-stroke architecture. When this combustion system is used in an extremely fuel-lean environment, high efficiency and near-zero NO_x emissions result. The use of direct injection and an oxidising catalyst ensures that hydrocarbon and carbon monoxide emissions are fully-controlled too. Omnivore also uses a variable charge trapping valve system to adjust port timing with the effect of completely smoothing the torque curve and providing a further lever on the HCCI combustion process through variable residual gas trapping.

Consequently what could be a form of ideal is achieved, although 4-stroke advocates would immediately claim that a piston-ported 2-stroke cannot be made as reliable as a poppet-valve 4-stroke. Again, it is necessary to re-adjust one's horizons and look beyond the automotive arena. In terms of overall engine life, a 'cathedral' diesel with piston-controlled intake ports performs eight to ten times as many strokes as an automotive engine over 150,000 miles (240,000km). Surely this fact alone gives enough headroom to accommodate engineering for adequate life in the automotive marketplace.

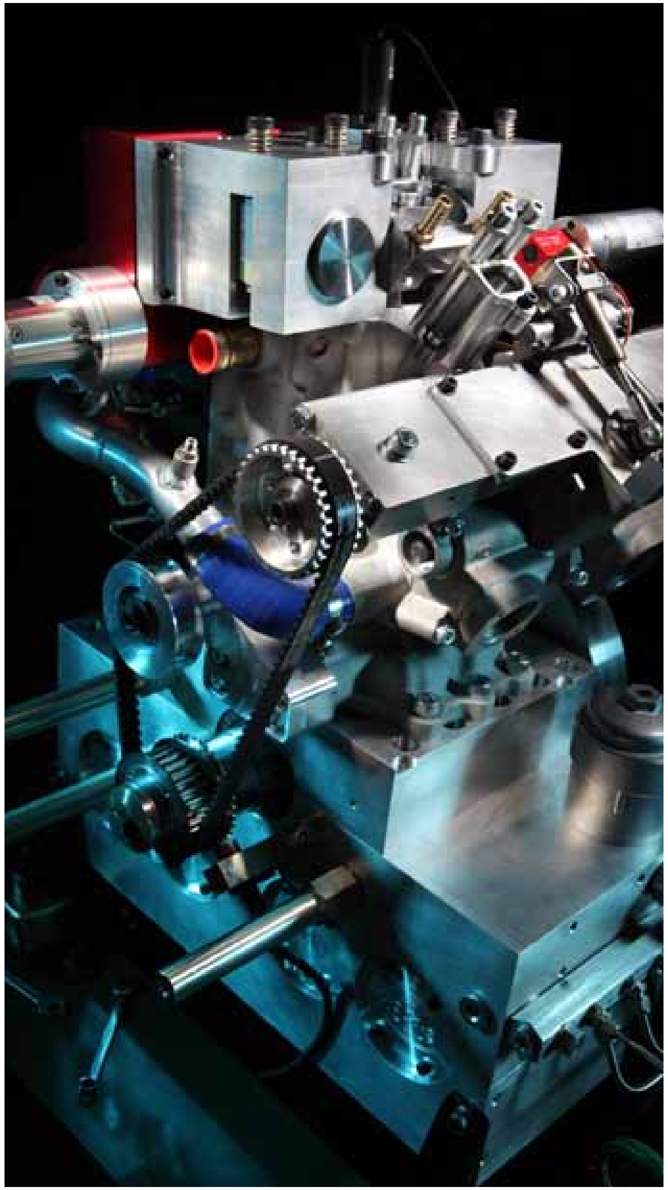
Could upsizing be the new downsizing?

Thus the stage is set for a re-imagining of what a light-duty engine could look like in the medium-term future. Consider as a baseline a downsized 4-stroke engine of 900cc and 150bhp operating at up to 35bar BMEP (250Nm). This engine would probably be a 2-cylinder with a bore and stroke of 83mm, a compression ratio of approximately 9.5:1, direct injection, a two-stage charging system and dual continuously-variable camshaft phasing. One could replace this with a 2.2-litre VCR 2-stroke engine (perhaps a 3-cylinder with approximate bore and stroke of 97.5mm, or a 4-cylinder with approximately 89mm bore and stroke) producing the same power and torque. However, the maximum BMEP would in this case be 7bar BMEP, allowing it to operate in full-range HCCI together with cheap after-treatment. Because of the low BMEP, mechanical stresses are significantly lower, meaning low reciprocating masses and consequently good NVH, especially considering the three- or four-times-higher firing frequency. This is where the true benefit of this type of upsizing is realised: lower loads mean reduced NOx emissions output and the reduced mechanical stresses mean consequently lower bearing friction leading to better fuel consumption. In fact, upsizing is a direction one would probably prefer to investigate with such a 2-stroke concept, because the associated throttling loss penalty of the 4-stroke engine is absent and there is the potential to avoid switching from SI to HCCI at all because the HCCI range is large enough to make this feasible with a low-BMEP, large-swept-volume engine. Since the scavenge pump for such an engine would likely be a non-chargecooled Roots blower or electric pump, the cost of the 2-stroke is expected to be compellingly lower than the heavily-downsized 4-stroke, even considering the requirement for the VCR system (which in itself can be very simple) and charge trapping valve.

Furthermore, from tests conducted at Lotus on our Omnivore research engine, there is the possibility to eliminate the ignition system completely in such an engine, helping to offset the cost of the DI system; this is because the Omnivore VCR engine can be crank-started directly in HCCI mode, with no requirement for a spark-ignition system. Inherent fuel flexibility in such an engine is a given, too – to date, Omnivore has been operated on 98RON gasoline, E85 and diesel. These possibilities offer the potential for such an upsized 2-stroke to be a viable technology path which is cheaper than a future mainstream 4-stroke. While on a drive cycle we would expect such a 2-stroke to have at least 10% better fuel consumption, in the real world the benefit would be even greater, due to the absence of component protection fuelling requirement. Throttle response and driveability would be significantly better, too.

In conclusion, adoption of the 2-stroke cycle permits consideration of other fuel consumption reduction concepts which are difficult to apply to the 4-stroke engine, and which, through the upsizing which is now possible as a result of the elimination of throttling loss, also allows new avenues to be explored with the potential for greater fuel efficiency. In such a scenario, upsizing could be the new downsizing.

Source: Lotus Engineering



Lotus Omnivore single cylinder engine

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