proActive

The official industry newsletter of Lotus Engineering

Issue 24
Jan/Feb 2008

Q&A with
Tesla's 'Car Guy'

Optical Access:
A closer look at Lotus' advanced combustion research

Lotus introduces:
'Safe & Sound' Hybrid

Welcome

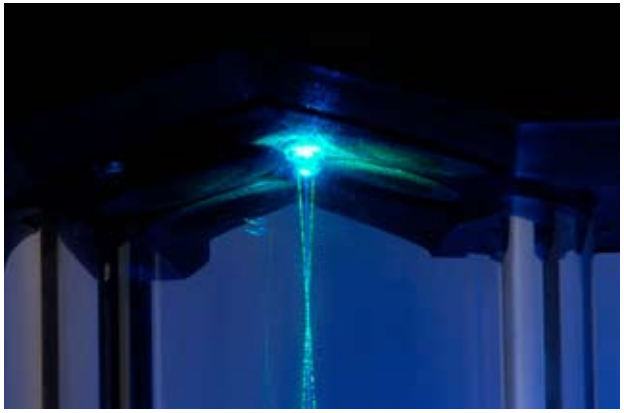
Welcome to the new look proActive, which with this 24th issue has now been providing a wide range of industry and Lotus news and features for four years. We haven't made major changes to our proven and popular format but we have taken the opportunity to freshen things up.

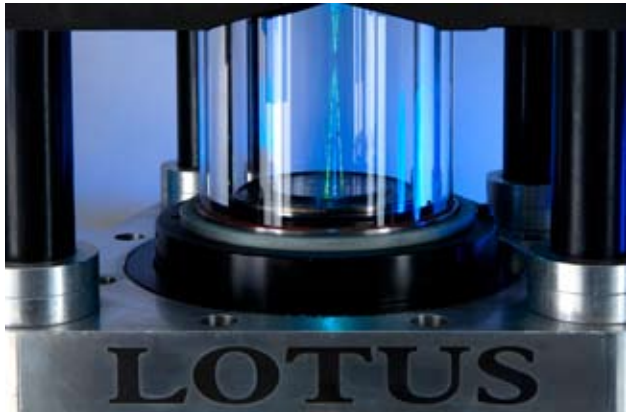
Developments in both Lotus Engineering and Lotus Cars make for truly exciting times ahead. Project Eagle, the new mid-range Lotus sports car is progressing well and the current projects and technologies for cleaner vehicles are thrusting Lotus to the forefront of green automotive engineering. As we take the business forward, it's not only proActive but the whole face of Lotus that is changing - you may have already seen the all new Lotus website, www.grouplotus.com. If you haven't, check it out.

In this new look issue, we look at the novel application of Lotus sound synthesis to improve pedestrian safety for hybrid vehicles, as well as a close up look at the advanced combustion research carried out with the Lotus optical access engine. We also have the first of a series of Q&As with leading industry figures. just-auto's David Leggett gets the ball rolling with an interview with Malcolm Powell of Tesla Motors.

As ever, we'd be interested in all your feedback. Enjoy issue 24.

Peter Morgan
Marketing Manager - Lotus Engineering





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> Seat has announced that it will invest in a solar power installation at its Martorell plant saving 11,700 tonnes of CO_2 each year

GENEVA PREVIEW: New Lancia, updated Ford to bow

The redesigned Lancia Delta will make its debut at the Geneva International Motor Show next month whilst Ford will show a Focus coupé-cabriolet restyled in line with the rest of the recently revamped range.

The new Delta is the first totally new car in Lancia's second century. Designed by the Lancia Style Centre, it is 4.5 metres long, 1.8 metres wide and 1.5 metres high on a wheelbase of 2.7 metres. A sliding rear seat with reclining squab gives added flexibility.

Available equipment will include Bose Hi-Fi radio incorporating a CD player and MP3 file reader with steering-wheel mounted controls, the parent Fiat group's Blue&Me system developed with Microsoft, also available in a NAV version, and a new satellite navigation system developed with Magneti Marelli.

A range of turbo engines, both petrol and diesel, will deliver 120bhp to 200bhp with a choice of six-speed manual, robotised and automatic transmissions.

ESC and technical features, claimed to be unique in this category, such as SDC suspension (with electronic damping control), will also be on offer.

Ford's updated Focus coupé-cabriolet, distinguished mainly by a remodelled nose, and with standard retractable hardtop will again be manufactured at the Bairo plant of Pininfarina.

"We also felt the importance of aligning this charismatic vehicle with our 'kinetic design' language as soon as possible," said Ford Europe sales and marketing chief Stephen Odell.

Most prominent amongst a number of detail interior changes is a new instrument cluster of a 'binocular' style with instruments illuminated in red.

Like other new Focus models, the coupé-cabriolet gains a flow-through centre stack to the standard 'premium' centre console with an increased stowage volume of approximately four litres and a sliding armrest with a travel of 80mm, both contributing to increased comfort and convenience.

New standard driver-assistance features have been introduced on all updated Focus models including a 'Ford Power' button for keyless start, plus keyless entry system, standard emergency hazard warning light activation system, optional tyre deflation detection system, new audio connectivity module for external devices and new levels of Bluetooth and USB connectivity, voice control and navigation systems.

New navigation systems include an 'affordable' navigation option with 'SD' card slot as well as a DVD based system with 7inch colour touch screen, and a DAB digital audio broadcast tuner is now offered with the Sony radio system.

Engine updates include additional refinement for the two-litre diesel; here in the UK 1.6- and two-litre petrol will also be offered, the latter with optional automatic gearbox.

Source: just–auto.com editorial team

SPAIN: Seat to generate solar power

Seat has announced that it will invest in a solar power installation at its Martorell plant saving 11,700 tonnes of CO_2 each year.

8.5 megawatts (MW) of solar photovoltaic panels will be installed on the roof of the automaker's corporate building and on a car park. The system will generate 11.2 gigawatt-hours (GWh) of electricity a year by the end of 2008.

The panels will cover 66,000 square metres. Additional panels will be added to the roof of assembly buildings at a later stage, covering a further 139,000 square metres.

Seat said that 20% of total investment in Martorell is dedicated to environmental initiatives. In January it opened a new rail line to carry vehicles from the plant to the port of Barcelona, removing 25,000 trucks from roads each year.

Source: just–auto.com editorial team

Industry **News**

> We aim to use renewable energy to the greatest possible extent and hydropower is the best alternative that our suppliers can offer at present

SWEDEN: Volvo Cars takes steps to become 'climate neutral'

Volvo Cars has reached an agreement with its energy suppliers to ensure that all electricity delivered to its plants in Sweden and Belgium is derived from hydropower. This is part of a plan for its European production operations to be 'climate-neutral'.

"We aim to use renewable energy to the greatest possible extent and hydropower is the best alternative that our suppliers can offer at present," said manufacturing chief Magnus Hellsten.

The agreement is with Vattenfall in Sweden and Electrabel in Belgium and covers all electricity contracted by Volvo Cars' purchasing department. The utility providers sell certificates to guarantee that all electricity delivered to the automaker in Sweden and Belgium has been generated from hydropower. The agreement covers about 1,000 GWh.

"This is part of our continuous drive to make our production climate-neutral, both as regards direct and indirect climate impact. In a future scenario, we will also be examining other types of energy for our production units, such as biogas and wind-power," said Hellsten. For space heating, Volvo uses mainly natural gas but in future it is planning to replace this with renewable biogas, according to the automaker's director of environmental protection, Mihkel Laks.

Like other vehicle manufacturers, Volvo Cars has also been actively seeking to improve the energy efficiency of its manufacturing operations. It says that although the areas it heats have almost doubled in size over the years, energy consumption has remained constant.

In recent years, this has started to fall thanks to on going efforts to save energy. A recent example is a review of the development and engineering departments' building in Torslanda. This resulted in energy savings of about 30% and an improved indoor climate.

"We are now carefully checking all our facilities. By applying our experiences from successful projects, we can quickly achieve major improvements," said Laks.

Source: just–auto.com editorial team

INDIA: Hyundai opens second small car export hub plant

Hyundai Motor opened a second plant in India to respond to growing competition and further consolidate the country's position as a global hub for small cars.

India already exports models such as Hyundai's Getz and Suzuki's Alto to global markets from its high-volume car plants.

Hyundai itself hopes new models and new factories in other emerging markets such as China will help it boost sales worldwide by 20% this year, Reuters noted.

Accoring to the report, Hyundai, the second-largest car maker in India, said it is prepared to fight greater competition from Tata's ultra-cheap Nano car unveiled on January 10th.

"We are not looking to compete with the Nano in terms of price, but we are keeping our options open," Hyundai Motor India president Ashok Jha told the news agency, referring to the Tata car priced at just over US$2,500 before taxes.

The proposed mini car would be a mass market model that meets all global standards, Jha told Reuters without elaborating.

The new factory in Sriperumbudur, near the southern city of Chennai, would double capacity to 600,000 units, second only to leader Maruti Suzuki India's planned expansion to 1million units by 2010/11, the report said.

The plant, which is adjacent to the existing plant, would largely be dedicated to making the new i10 for local and export markets, Hyundai Motor chairman and chief executive Chung Mong-Koo said, adding: "Hyundai Motor India will play its role of a global manufacturing hub for all of Hyundai's small car models."

Hyundai has spent US$1bn on the new plant. According to Reuters, Jha said a new 300,000-unit engine and transmission plant would be operational later this year.

Reuters noted that annual passenger vehicle sales in India are estimated to nearly double to 2m units by 2010 due to rising incomes and new model launches. Hyundai is aiming for a quarter of the market in 2008, up from just over 20% now.

Hyundai sold 327,160 vehicles in India in 2007, up 9% from the previous year. Sales of models such as the Santro and Getz hatchbacks rose 8% in the domestic market, while exports climbed 12%, the news agency added.

Hyundai reportedly said it aims to make 530,000 vehicles in 2008, is expanding its local dealer network to 300 from 230, and will export to 90 markets, up from 73, from the port city of Chennai.

Hyundai is also talking to Indian firms about a possible venture for commercial vehicles, Reuters noted.

Source: just–auto.com editorial team

> This keeps Lotus Engineering at the forefront of advanced combustion technologies, which will find their way into engines of the future

Lotus Engineering continues senior fellowship with Loughborough University

Lotus Engineering, the world-renowned automotive consultancy division of Group Lotus plc, announced its continued collaboration with Loughborough University through the sponsorship of the Group Lotus Senior Research Fellowship into Laser Diagnostics. The research activities will continue to focus on reducing internal combustion engine emissions.

Lotus Engineering originally started working with Loughborough University in 1997 and the Group Lotus Fellowship was created four years ago to develop the cutting-edge research programme HOTFIRE. This high-technology research programme, in conjunction with Siemens VDO (Now Continental Automotive), UCL and EPSRC, resulted in an innovative approach to improving fuel efficiency and emissions from a gasoline direct injection engine.

The Group Lotus Fellowship is held by Dr Graham Wigley of the School of Aeronautical and Automotive Engineering and Systems Engineering, who will continue the research into advanced combustion using the Lotus optical research engine and laser diagnostics. This cutting-edge research is integral to Lotus Engineering's ongoing activities into new and world-leading techniques and technologies to reduce the environmental impact of the internal combustion engine.

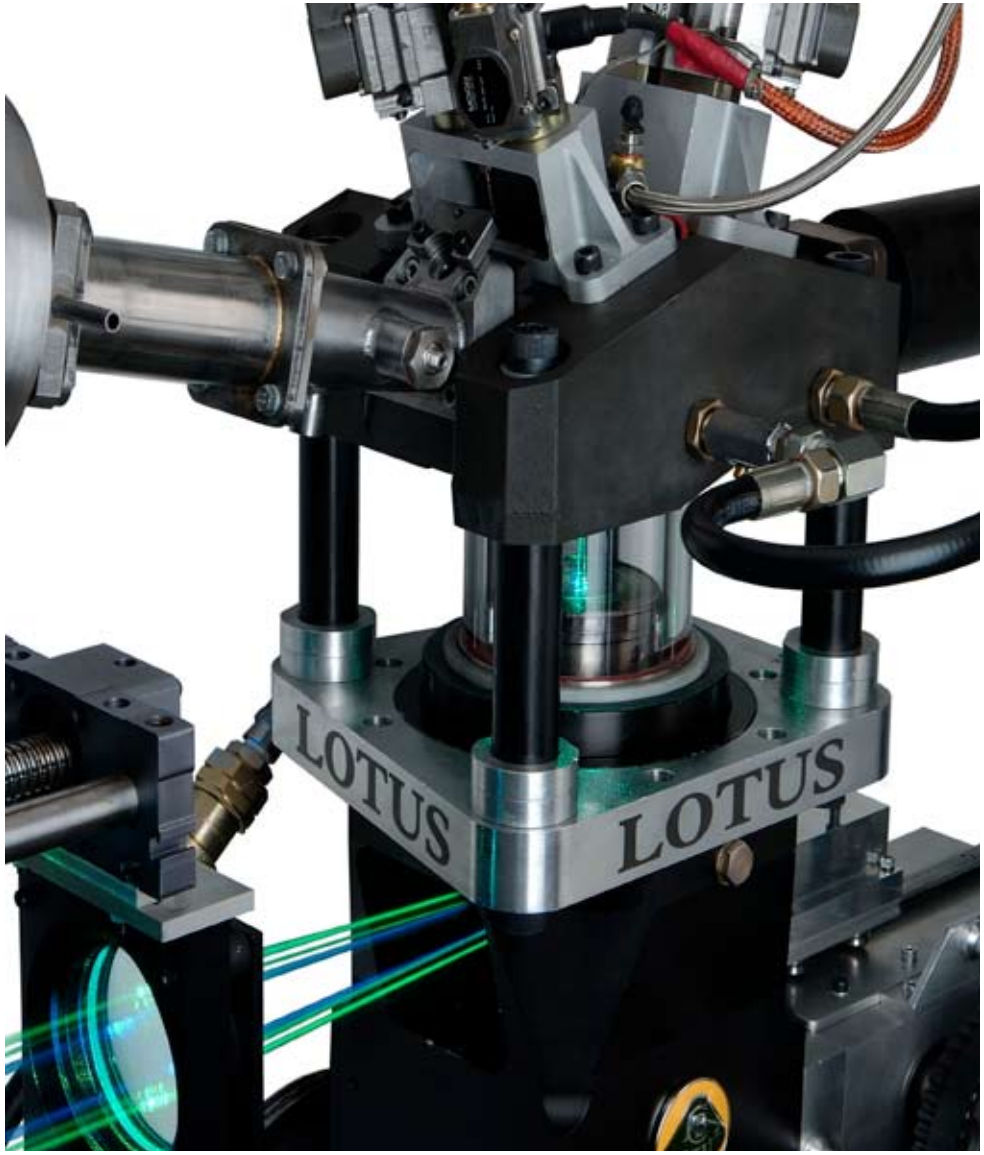
Simon Wood, Technical Director of Lotus Engineering said: "This collaboration provides Dr Wigley and his team the opportunity to continue this exciting research. By using the Lotus optical access research engine with Loughborough's laser diagnostics expertise, we are able to look inside the engine to understand the interaction of the air motion and fuel spray in the cylinder. This keeps Lotus Engineering at the forefront of advanced combustion technologies, which will find their way into engines of the future."

Mike Kimberley, Chief Executive Officer for Group Lotus plc further commented: "I am delighted that we will carry on working closely with Loughborough University, one of the most highly regarded educational institutions in the United Kingdom.

"This is an excellent example of an industry and academic partnership producing world-class research for the benefit of the environment, the car buyer and maintaining the UK's position at the forefront of technology."

Dr Wigley remarked: "Over the years a highly productive working relationship has been developed and state-of-the-art experimental facilities have been established for studying the air-fuel mixing and combustion for advanced gasoline engine technologies. The continuation of the Fellowship helps maintain the high level of momentum and expertise developed by the research team."

Source: Lotus Engineering



> “These driving conditions give the media an opportunity to drive the car for a few hours, concisely appraising Hethel’s latest as a “First Steer” ”

Sunshine in Catalunya

Lotus does not conduct many press first drives away from the Hethel factory - with a test track, fabulous quiet roads (one of the reasons why Lotus cars ride and handle so well) and brilliant photographic back-drops, who wouldn’t want to come to the home of Lotus?

But, even with all this on our doorstep, sometimes going further afield than Hethel can be of benefit: January at Hethel can be pretty chilly and damp, the roads are slippery and the cloud cover extensive. So to launch the Lotus Elise SC, most powerful and fastest Elise yet, a location of Barcelona, in southeast Spain was chosen - great roads, near guaranteed sunshine and a fine Lotus dealer for behind-the-scenes support.

Six fabulous Elise SC (220 PS supercharged 2ZZ VVTL-i engine), four left hand drive and two right hand drive were driven by the press over a two-week period, taking in some excellent roads. A suggested drive route of 150km followed long sweeping roads, motorways, a tight and twisty mountain pass and of course a town and a city environment. These driving conditions give the media an opportunity to drive the car for a few hours, concisely appraising Hethel’s latest as a ‘first steer’.

So how did the launch go? The media coverage so far speaks for itself:

5th Gear Review
Yahoo Cars Review
AutoExpress Review
AutoCar Review

Source: Group Lotus plc

Lotus launches new website

Lotus launched a new website (http://www.grouplotus.com/) at the beginning of February, marking the latest development in an ongoing programme of exciting changes for the expanding brand.

Committed to driving forward with technology for both Lotus Cars and Engineering clients, Lotus follows this vein with a new and improved website which is easy to navigate, cool and modern. Visitors can observe today’s Lotus; a technology-focused, environmentally-aware company that is passionate about delivering the finest sports cars and high-technology engineering, globally.

Mike Kimberley, Group Lotus CEO spoke about his future plans for the international marque: “In 2008 Lotus will be celebrating 60 years of the Lotus brand - a fantastic celebration of Britain’s finest prestige sportscar brand and an apt juncture to communicate how our company will evolve going forward. We are committed to developing and implementing technological solutions to all facets of our business, and using online media to engage our customers and communities is something we embrace. We believe that with the introduction of our latest website we can present visitors with the doorway to our excellent products and services.”

With sophisticated looks and an informative and exciting format, the Lotus website is designed with evolution in mind, ready to adapt and develop with the changes planned by Kimberley. 2008 will see the start of production of a new sportscar, code-named Project Eagle, and the new high-end supercar, a replacement for the legendary Lotus Esprit will be launched in 2010.

Source: Group Lotus plc

> A Lotus Optical Research Engine had already been installed and commissioned at KACST

Lotus Engineering & KACST cooperate to establish technology base for the auto industry in Saudi Arabia

Lotus, via its engineering division, has entered into a joint cooperation programme with KACST, the King Abdulaziz City for Science and Technology, with the intention to promote the establishment of an ecologically-driven automotive technology capability in the Kingdom of Saudi Arabia.

Lotus, with support from its parent company PROTON, has been commissioned to assist with the long-term strategy of KACST to create an automotive research, development and test centre to support the manufacturing infrastructure within the Kingdom to help build its industrial capabilities and potentially utilise its vast natural resources.

Lotus has already been involved in the first stage of this objective with the installation of a new engine and test cell facility in the Kingdom. This programme, which started in 2006, was commissioned with Lotus Engineering and uses the highly-sophisticated Lotus Optical Research Engine.

His Excellency President Dr Mohammed Al Suwaiyel said, "The comprehensive strategy of KACST is to achieve automotive design, development and testing capability for Saudi Arabia within a ten-year period, commencing in 2008. A newly-established team of highly skilled automotive engineers from KACST, Lotus and PROTON will also enable the partners to develop a technology base for the automotive industry in Saudi Arabia."

Mike Kimberley, Chief Executive Officer of Group Lotus Plc, said, "Lotus and PROTON are committed to assisting KACST in achieving its objectives. The engine and test cell programme was the start of a successful relationship and the conclusion of this joint cooperative study will drive the total automotive industry strategy for the Kingdom of Saudi Arabia."

PROTON managing director Dato' Syed Zainal Abidin Syed Mohamed Tahir said the combined wealth of experience that Lotus and PROTON have will be beneficial for Saudi Arabia to develop its automotive development and manufacturing capability.

"PROTON has had the distinction of technology transfer from established automotive manufacturers as well as its own developed home-grown capabilities. Together with Lotus' engineering expertise, Saudi Arabia will have access to a greater depth of knowledge for the launch of its automotive industry," he added.

Prince Turki bin Saud bin Mohammad Al Saud, the vice president for Research Institutes at King Abdulaziz City for Science and Technology, said, "Lotus Engineering will take a lead role in the partnership supported by PROTON with continued expertise throughout the project.

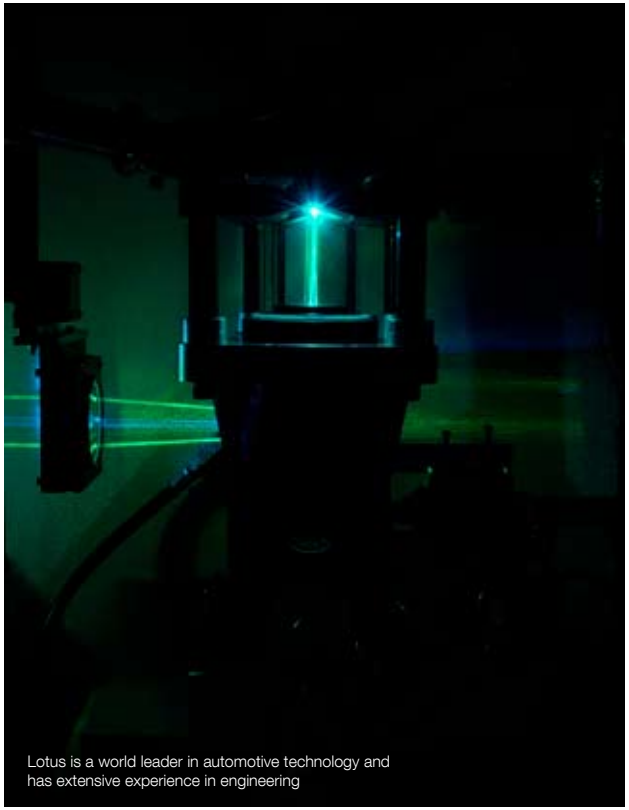
"Lotus is a world leader in automotive technology and has extensive experience in engineering, manufacturing and testing facilities globally including many of the proving grounds in Europe and around the world."

"An Automotive Research Development Centre will be established in the Kingdom of Saudi Arabia with full testing facilities that can be used by other vehicle manufacturers."

To enhance the engineering and manufacturing skill base in Saudi Arabia, Lotus and PROTON will be providing training in all aspects of automotive engineering to KACST employees, utilising facilities at the Lotus headquarters in Hethel, Norfolk, as well as PROTON's facilities in Malaysia.

Mike Kimberley said: "Lotus is ideally placed to support KACST as we have extensive experience in both niche and high-volume vehicle and engine development and manufacture. Lotus Engineering continues to provide high-technology engineering consultancy for the world's automotive industry and our world-class research and development is unprecedented.

"We are pleased to be working closely with KACST and PROTON on this exciting challenge to initiate a technology base for the automotive industry in the Kingdom of Saudi Arabia and to develop an infrastructure to increase the ecological capabilities of the industry."



Lotus is a world leader in automotive technology and has extensive experience in engineering

Prince Turki bin Saud bin Mohammad Al Saud said: "The cooperation is consistent with the national industrial strategy and the mission of the industrial cluster programmes that emphasise the creation of an automotive industry in the Kingdom."

He added: "We need to develop environment friendly technologies in order to sustain the utilisation of oil with less harmful effects to the environment."

Source: Lotus Engineering

Q&A with Tesla's 'Car Guy'

> "It will be some hundreds of cars this calendar year – we should be running at around 600 for the model year."

Malcolm Powell is VP Vehicle Integration at Tesla Motors, the California-based technology firm developing an electric sports car that will be contract manufactured by Lotus in Hethel. He is responsible for the engineering of the car and ensuring that it meets all the necessary standards prior to entering production. just-auto's Dave Leggett interviewed him on behalf of proActive

DL: When will those Tesla customers who have already put money down receive their cars?

MP: We're still on plan for the first customer to get his car in the first quarter of this year.

DL: So when does series production start then?

MP: It depends what you call production. We're doing a very controlled ramp rate, a prudent and sensible thing to do. We want to make absolutely sure that the production cars are working as anticipated and that the whole process and supply chain is working before we ramp up production further.

There is a danger when you ramp that you keep an eye on the big balls, but it needs all the balls to build the car; it's no good having just 99% of the parts because you can't build it. So we will control our ramp rate carefully. We will start producing the cars this quarter and we will monitor and ramp as quickly as we can, but under control.

DL: And what sort of volume are we looking at for the first year of production?

MP: It will be some hundreds of cars this calendar year – we should be running at around 600 for the model year.

DL: And building up to what level?

MP: We have always targeted the capacity to be able to build 2,000 cars a year. That's because we have to have targets to choose appropriate tooling investment for the components. If the demand is absolutely extraordinary then we could choose to make more.

Tesla aims to deliver supercar acceleration and an acceptable top speed

It's very difficult to predict exactly where demand will be on a new product such as this. We had to set a level that was achievable to fix our investment – and that was 2,000 a year.

DL: I understand the Tesla Roadster's transmission has been a major source of delays to the programme schedule. What has been behind the problems in that area and how are the problems being overcome?

MP: You might think that a transmission is a known technology, particularly when viewed against all the new technology being incorporated into the car, but it's not that simple.

As a new company it was difficult, initially, to get major manufacturers to even talk to us, never mind commit any resource to actually help design, engineer and build systems. We started off going down a particular route with a transmissions supplier and we got to the point where we realised that the way that particular programme was headed, it wasn't really going to meet our performance targets for the car.

We chose, pretty late in the programme, to change course and go with an alternative supplier with a different approach.

The transmission sounds simple: two-speed transmission and therefore you depopulate a regular transmission, but if you think about it, our gear shift between first and second is a factor of two and the motor spins up to 13,000rpm, so first gear takes you to over 60mph and second takes you to over 125mph so that is a huge ratio step against which we don't have a conventional clutch.

There's a rotor with a very high inertia and we have to change the speed of that rotor very, very quickly to give us a performance shift. There are also issues about electrical isolation because of the way we use the charging system and the motor.

So, it isn't straightforward. It isn't 'just another transmission' and some issues have been thrown up that weren't anticipated and have taken longer than we had hoped to resolve. With change of supplier, change of design concept and with some of these unforeseen technical issues to overcome, delays have been the result.

Q&A with Tesla's 'Car Guy'

> "The uninitiated look at the car and say it's the same as the Elise, where is all that additional weight?"

Many customers have said they would rather have the car now with the single gear and current level of performance than wait any longer.

DL: Just following on from that, the first Tesla Roadsters are being fitted with an 'interim transmission' that can be upgraded later on. What are the performance implications of that? Will the first cars off the line be capable of doing 0-60mph in under four seconds?

MP: The point about the interim transmissions is that they will effectively be locked in second gear. A lot of the prototypes have been running like that for some time and the vast majority of customer drives have been done like that and the feedback has actually been that the car hits performance expectations in that state – it still does 0-60 in something like six seconds.

So you've now got a rather interesting car that you can drive very rapidly from zero up to its top speed in one gear. I don't think customers will be too disappointed.

The reason for the two-speed set-up was because the torque capacity of the motor and the power system was 'X' and to be able to say to the world 'electric cars aren't just golf buggies' we needed the ratio to give us the four seconds and the top speed. In a single gear to begin with it would have done 0-60 in say 5.5 seconds with a top speed of 100mph.

That would have been fine, but we wanted to make it clear that we could deliver this sort of supercar acceleration and an acceptable top speed. That means two-speed shift – which is doable but it's just a question of time and money.

It's important to stress that we have had very positive feedback from customers about the second gear and that's the only reason we're doing this: many customers have said they would rather have the car now with the single gear and current level of performance than wait any longer. This is about satisfying customer demands to deliver before we get the full performance of the vehicle.

DL: Can Tesla's lithium-ion battery fully meet acceptable performance parameters and will the battery last 100,000 miles – does it degrade over the lifecycle?

MP: Sure, they do degrade and it's all about charge cycles. The battery manufacturers do the testing to determine what the battery capacity is. They fully charge, then fully discharge and keep doing that – it's actually pretty abusive to a lithium-ion battery.

In the case of lithium-ion, keeping it charged up is actually a good thing to do – you don't need to fully discharge them the way you need to with some other batteries.

The other thing is temperature control. That charge-discharge cycle that the battery manufacturers have to do is pretty abusive to the battery because of the temperature the battery gets to.

We are aware of all these things and we pay very detailed attention to the management of the batteries because that is so critical to what we're trying to achieve.

How we charge them and what capacity we charge them to, and how we maintain temperature – because they are actively cooled within the car – is all about preserving battery life.

Most people don't drive many miles on average each day – and we know this is not a road trip car – meaning they won't be using a huge percentage of the battery pack each day. So, we say, when you get home just put the battery on charge and that will keep it in good condition.

If we take the standard fairly abusive battery charge cycles the battery manufacturers carry out, that implies driving say 200 miles in one stretch before recharging each time and that works out at 100,000 miles of life. And that's with that rather unrealistic implied usage pattern. In reality, the battery should be good for more than 100,000 miles.

Q&A with Tesla's 'Car Guy'

> We, at Tesla, have enough to worry about with the new technology, without having to also worry about a lot of the other stuff that goes into making a car

Also, the battery makers say that the battery life is over when it only achieves 80% of its original performance capacity.

So, there will be some degradation of range over the life of the battery. When new you will get over 200 miles range on a full charge but over time you will notice some degradation on that. But it will be a slow process and even under the extreme battery testing regime of full charge-discharge, that yields 100,000 miles with end of life deemed at 80% of original capability. Performance will also tail off slightly but when you start with 0-60 mph in 4 seconds, you'll still have a pretty amazing car.

DL: In terms of readying the Tesla Roadster for production, what has been your experience in meeting US federal regulations in areas such as safety?

MP: It's frightening and scary in terms of all the things you have to do, but it is also fairly straightforward. I've been in the industry a long time now and it's a case of knowing what needs to be done and getting on with it. From the outset we knew we were designing for the federal market so things like headlamp design, crash testing and so on, were known factors. We just had to go through the process.

We have had to run certain rig tests on certain parts of the car because it does carry more weight than the Lotus Elise – the Tesla is significantly heavier. The uninitiated look at the car and say it's the same as the Elise, where is all that additional weight?

Actually it's not the same car. For example, the crash structure at the front has new components in it that add load bearing paths and we have changed the aluminium chassis as well. Although the chassis is based on Elise technology it had to be changed in many respects, such as the fundamental siderails – these are a unique extrusion for the Tesla. The chassis is different. We have had to build significant reinforcement and strength in to those parts to control the mass of the battery pack as it is restrained during impact.

The pack weighs over 900lbs – it's a significant lump of mass.

The motor and transmission are relatively light and we don't have to carry a fuel system, but fundamentally the car is a lot heavier than an Elise.

The important thing is: we know all that and we have designed accordingly and have recently completed all the required safety and crash tests. We're just getting all the final certificates in place that enable us to ship production cars.

DL: How does the supply chain work on the Tesla Roaster?

MP: Having chosen to work with Lotus as the contract manufacturer, we decided that there was no point in reinventing the wheel. We're using the Elise structural concept, so anything we can carry over from the Elise makes a lot of sense. We at Tesla have enough to worry about with the new technology, without having to also worry about a lot of the other stuff that goes into making a car.

We have three categories of parts:

- Some parts are 100% Lotus carryover, things like the windscreen wiper. So we simply tap into the Lotus supply chain for them.

- Then there is a second category, which comprises new design or modified parts where it still makes sense for us to use the Lotus suppliers. So Tesla has design responsibility but we use the Lotus supply chain to procure those parts and deliver directly to the plant in Hethel.

- And thirdly, there are the totally unique Tesla designed and Tesla procured parts. This category includes some simple parts that the supplier can ship to Hethel for final assembly, but also includes more complex elements such as the motor, which we make at our dedicated plant in Taiwan where we do all the manufacturing, testing and then put it in box to ship to Hethel.

DL: How difficult is coordinating the manufacturing and assembly process?

MP: The fundamental logistics is fairly straightforward in terms of things like shipping. But as a new company it's been a hurdle to get our own systems in place so that we know exactly where we are. We've had to develop systems from scratch. Not only have we been designing a fantastic vehicle that uses new technology but at the same time we have been building a company, developing news systems, training people for those systems and making sure that the systems are working correctly – all from a clean sheet of paper. It has been a big challenge.

In terms of what we have done in the time available it has been a very rapid programme.

There's still engineering change going on now to resolve some final issues and improve the product. Unfortunately it's engineering change that actually interferes with the supply process. Yes, it's a challenge.

DL: What's the current thinking on successor models?

MP: Tesla's intent has never been just to make the Roadster, but the Roadster acts as a technology pioneer. It has already provoked the industry to take more note of electric cars. Great.

But the Roadster is not our only game. Our game is to get as many electric cars on the road in the world and cut our dependency on oil.

So for us it's also about making more vehicles – such as a sports sedan so that we can appeal to a broader market. We have got to get the volume up so that we can start getting the price down. We have learnt a lot and we know we can improve still further with future product.

The next car has to appeal to a wider market, as does the car beyond that.

We are also up to talk to OEMs to see where we can help anybody else to do this because we do not intend to be the only people in the

Q&A with Tesla's 'Car Guy'

> "I'd been at Lotus a long time and achieved a lot – and I enjoyed it – but I'd got to a time in my life when I was needing a different sort of challenge"

world making electric cars because that doesn't provide a sufficient solution.

DL: For you personally, how has the experience working for Tesla been?

MP: I'd been at Lotus a long time and achieved a lot – and I enjoyed it - but I'd got to a time in my life when I was needing a different sort of challenge.

I never perceived myself as being particularly green. I think, like most people, I cared but wasn't doing anything proactively about it.

When I got involved in Tesla and the philosophies behind it, I was attracted. So many firms produce electric cars that you just don't want to drive – but Tesla is about turning that on its head and producing a car that delivers performance, that you want to drive and doesn't burn oil, so it is also good for the environment. And the idea is to force real change.

Technically, it was interesting to me and morally I thought 'yes, I could help to do something and why shouldn't I get off my backside and actually make a difference?'

I was very lucky to be in a position where this opportunity came up. And I was in a position to help both Lotus and Tesla and act as a bridge between the two companies. Tesla needed somebody from the automotive industry – it was an ideal opportunity for me and a good fit for both companies.

For me it's been a mixed bag. It's been incredibly exciting and challenging and has meant working with a totally different group of people – so many of them not automotive, so they would challenge everything. Sometimes I would have to explain how the industry works the way it does, but sometimes the challenges would make me think 'why do we do it that way?'

Sometimes you need that different set of people with different thought processes to just challenge what you're doing and look for better ways of doing things. That has been immensely rewarding.
The other thing I would say is that the nature of my role is to find problems, help teams resolve issues, keep the project on schedule as best we can. That's my role and you don't do that by looking at all the things that are going right – you look at the things that aren't going as well as you'd hoped.

Continually looking at problems can be de-motivating at times and some days are worse than others. But if I sit in a prototype and go for a drive I think 'this is why I am going through this pain'. It really is such an awesome car to drive and you realise the scale of the opportunity ahead for Tesla and everyone who wants to start thinking about electric drive.

We've just got to get there and we will get there – it just hasn't been an easy road.

Malcolm Powell

Throughout his career, Malcolm Powell has had the opportunity to drive some of the world's most amazing cars – and what he found is that beauty and acceleration are no match for balance and responsiveness. Bringing with him the desire to make the driving experience more physically interactive and less remote, Malcolm oversees the integration of all constituent parts of a Tesla Motors vehicle, including packaging, testing, and legal approvals.

After graduating with a degree in mechanical engineering from the University of Sheffield in the UK, Malcolm's first job landed him in the research department of Westland Helicopters, developing a remotely piloted surveillance helicopter. He then moved on to Ford of Europe, where he worked in the Special Vehicle Engineering division on "fun" cars (think small cars, big engines, all-wheel drive). Prior to joining Tesla Motors, Malcolm established an automotive design consultancy and then completed a 17-year stint at Group Lotus PLC, where he managed development of the North American version of the Lotus Elise.

Leaving three adult children behind in the U.K., Malcolm and his wife now live in San Carlos, where they spend weekends hiking and cycling to explore their new environment. That is, once they've finished video-conferencing with the kids back home.

Source: just–auto.com editorial team

Optical Access: A closer look at Lotus' advanced combustion research

> Lotus Engineering originally started working with Loughborough University in 1997

The recent announcement of the continuing research relationship between Lotus Engineering and Loughborough University is excellent news for keeping us at the cutting edge of combustion understanding. The highly advanced optical access engine central to this activity warrants a closer look, as does the research success so far.

Lotus Engineering and Loughborough University originally started working with each other in 1997. Lotus Engineering wanted to build a portfolio of combustion system knowledge from the research rather than the development perspective. Loughborough emerged as the ideal candidate to assist our research activities and an informal association developed. This led to the first work being jointly performed by Lotus Engineering and Loughborough University looking into the fundamental characteristics of gasoline direct injection spray systems.

The early work was performed on an atmospheric spray bench where the injection was into still air conditions, but it was always recognised that to look at the system properly, the correct engine environment would be needed. And to understand exactly what was going on in the engine meant being able to actually look inside it.

Following a pooling of ideas it quickly became apparent that there were no designs of optical engines on the market that met the needs of Lotus and Loughborough and their research aspirations. The question was asked: if we wanted the ideal optical engine what would it look like? Lotus then set about designing and developing such an optical access engine.

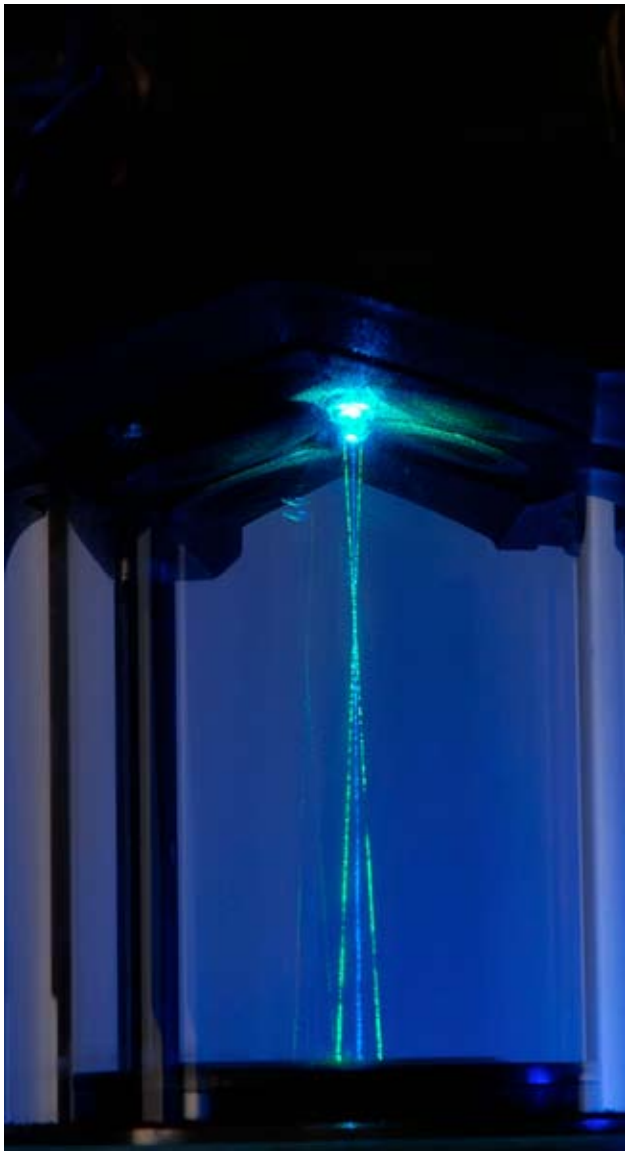
The design comprised a full-length fused silica liner to allow us to see inside the entirety of the cylinder and provide a side view into the pent roof. A sapphire piston window makes it possible to look upwards directly into the pent roof area. The engine needed to run under as realistic conditions as possible, and to this end both primary and secondary balance shafts were used to allow the engine a top speed of 5000rpm. Work was also performed to find an ideal material for the piston compression ring which had to slide against the glass liner walls without scratching, and maintain an appropriate seal to obtain the correct compression pressures. The resulting engine allows full optical access into the combustion chamber from bottom dead centre and into the pent roof. The engine was designed, built and commissioned at Lotus at the end of 1999 and installed into a laboratory at Loughborough in the early part of 2000.

The optical access engine works with the full suite of laser diagnostic tools available at Loughborough University. These have been central to all the detailed combustion research undertaken since the engine was commissioned and have enabled unprecedented visualisation of the motion of air and fuel in the combustion chamber.

A variety of techniques were introduced as the research progressed, the first of which was Laser Doppler Anemometry (LDA), which measures fluid velocities at a point where two laser beams are caused to cross. To provide information on the full flow field, this crossing point is scanned across the engine cylinder to discrete pictures, and the whole field can then be measured. The system measures the velocity over time, and therefore can be used to build a picture of how the in-cylinder flow changes throughout the engine cycle.

At a later date, a second technique was employed to measure flow fields. In this new system, Particle Image Velocimetry (PIV), two laser light sheets are projected into the flow at slightly different times. The flow is seeded with tiny particles and the light from these particles is collected by a camera. Knowing the time between the two light sheets, a mathematical cross correlation can be performed between the two images to see how far the particles have moved, and hence determine the velocity. LDA and PIV are complimentary techniques, both giving their own unique insight into the flows in the engine cylinder. LDA gives a good temporal description of how the flow develops at a point, while PIV provides a spatial description of the complete field at one instance in time.

A slight modification to LDA forms a new technique called Phase Doppler Anemometry (PDA), which can be used not only to determine the velocity of small droplets from an injected spray system, but also the size of the individual droplets as they pass through the two crossed beams. Again, this is a temporal measurement system, and so allows the development of the spray to be determined, both in terms of velocity and drop size. The complementary spatial technique to this is straightforward imaging of the spray with a fast camera and flash light system. This allows the morphology, or shape, of the spray to be readily seen, and additionally gives a quick method of determining the penetration of the liquid spray, particularly



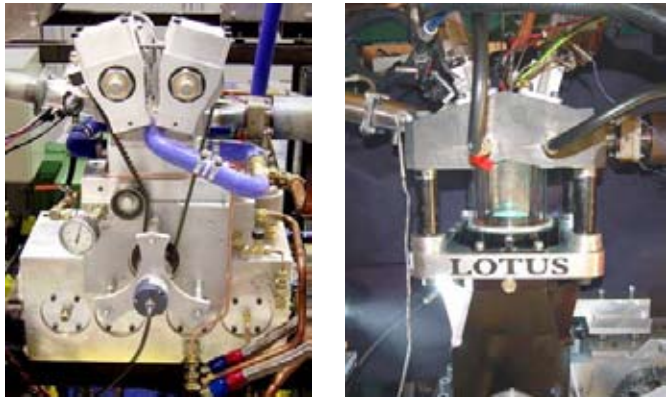
Optical Access: A closer look at Lotus' advanced combustion research

> By the start of the new millennium it became apparent that the association had developed to the point where it needed to be formalised

under different in-cylinder conditions. This imaging system, without the flash lamp, can also be used to look at the combustion in the cylinder, which allows a measure of the flame velocity to be found; and by using optical filters in front of the camera lens, this can also see which species of combustion products are in the cylinder.

These imaging systems, although good for liquid fuel, are unable to see the fuel once it has gone into its vapour phase. In general, this means that they cannot visualise the fuel distribution at the time of spark ignition. To obtain data on this, there is another laser technique employed called Laser Induced Fluorescence (LIF). Here a laser light sheet is projected into the flow, normally in the ultra-violet wavelength, and this light sheet causes the fuel vapour to fluoresce, and again using a filter in front of the camera lens, this fluorescing light can be collected, giving an indication of the fuel vapour concentrations in the engine cylinder at the time of the spark. To cause the vapour to fluoresce, the correct wavelength of laser light is required, and if it is not possible to change the wavelength available from the laser, then tracer dyes have to be added to the fuel for these measurements, where the dyes are chosen both to fluoresce at the laser wavelength, and to closely follow the fuel in terms of their vaporisation properties. This method can be extended to obtain a quantitative measure of the local air/fuel ratios in the cylinder.

By the start of the new millennium it became apparent that the association had developed to the point where it needed to be formalised, particularly around the collective aspiration of the partners over lowering vehicle emissions and improving fuel economy. In 2001 the Group Lotus Research Fellowship was signed with Loughborough University, with Dr Graham Wigley as the research fellow. In 2004 Lotus and Loughborough extended this agreement by funding the Group Lotus Senior Research Fellowship aimed at allying Lotus' expertise and equipment with that of Loughborough.

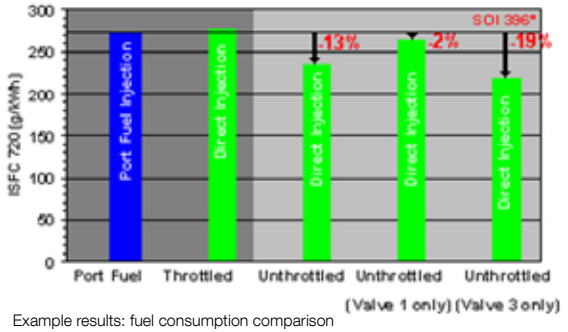


The two single cylinder research engines (Left: UCL, Right: Loughborough)

In September 2004, the HOTFIRE project started. The project was a collaborative piece of work by Lotus Engineering, Siemens VDO (now Continental Automotive), Loughborough University, University College London (UCL) and the Engineering and Physical Sciences Research Council (EPSRC) which provided funding. With increasingly stringent emission criteria and the need to reduce CO_2 to minimise the impact of vehicles on global warming, new techniques and technology have to be applied to the design of any new engine. The objective of this work was to study homogeneous direct central injection coupled with variable valve events to reduce engine out emissions and improve fuel economy. Additionally, two students would use the project to study for their PhDs, one at each university, providing two highly-trained personnel ready for entry to the automotive industry and fully conversant with the latest knowledge in GDI and related diagnostic techniques.

Due to the way a stratified combustion system functions, a further emissions reduction technique is required, called a lean NOx trap. This is an extra cost to any vehicle and also requires regular purging which involves bringing the engine out of the fuel saving stratified mode of operation. For these reasons, a homogeneous and stoichiometric combustion system was chosen to avoid the need for a lean NOx trap, requiring instead only the conventional three-way catalytic converter.

Two single cylinder research engines were purpose-built for this project. The first was a modified optical engine, incorporating Lotus' Active Valve Train AVT system, and situated at Loughborough. The second was a non-optical form of the engine, using conventional camshafts, at UCL. One of the objectives was to ensure that any combustion system could be used with currently available technology, hence the cam based version at UCL which could be used to simulate cam profile switching and cam phasing. The engines employed a close spaced central injection system using a multi-spray injector. The criteria for any improvement in fuel economy



Example results: fuel consumption comparison between PFI and DI injection strategies

and emissions were to be judged against the engines performance using port fuel injectors which also were fitted to both engines.

It was important that the two engines had identical performance criteria, as the non-optical engine was to be used for emissions and fuel consumption studies, while the optical engine was to be used to study the in-cylinder air motion, the air fuel mixing and the combustion. To this end-both engines had the same combustion chamber geometry, and identical inlet and exhaust systems. To test the engine, a fixed cam profile and valve timing were run on the non-optical engine at wide open throttle and the indicated mean effective pressure was determined. The cam profile was a low lift, short duration profile aimed at a low load condition. The same measurement was then performed on the optical engine, and extremely good agreement was found between the two, better than 2%, lending confidence to the ability to compare the different measurements between the two engines.

The work programme for the project involved designing small lift, short duration cam profiles for the inlet valves, which allowed the engine to be run with low and medium loads without the need for heavy-throttling. This gives an immediate advantage in fuel economy, as it reduces some of the losses incurred in pumping work with a heavily throttled engine. As the fuel system was direct injection, the fuel could always be injected at a time after the exhaust valves closed, and this leads to a saving in the emission of unburnt hydro-carbons as there is now no direct route for the fuel from the injection to the exhaust ports. All the fuel measurements, emissions

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> "The recent announcement confirms the importance of the relationship and the research within Lotus' work on developing cleaner engines and vehicles"

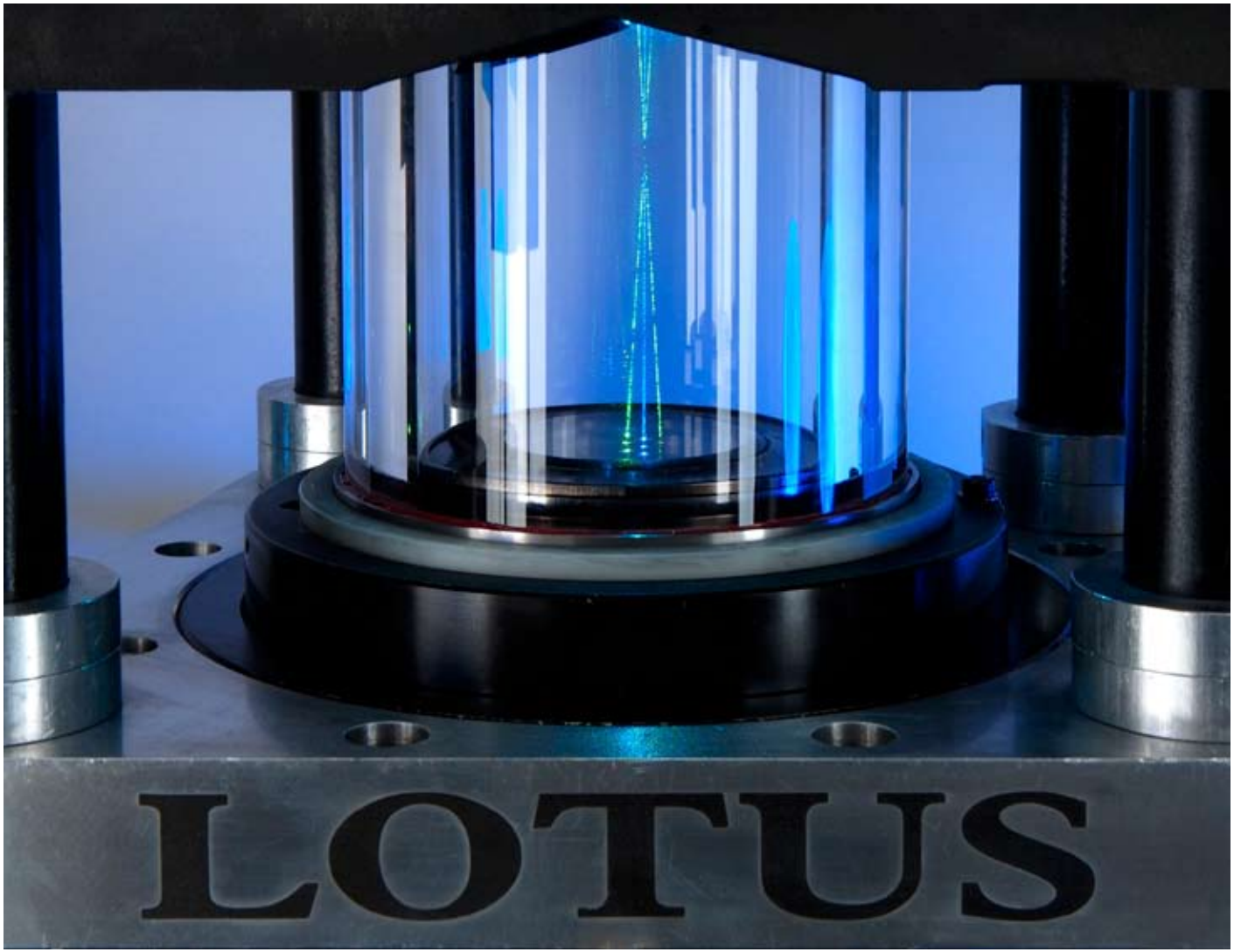
and particulates measurements were performed on the non-optical engine. The identical engine conditions were run on the optical engine, where the flow fields, air/fuel mixing and combustion were studied. The combination of these two sets of experiment allowed for a better understanding of the effects being measured on the non-optical engine.

The project is fast approaching completion and has proved very successful in meeting the objectives set out at the beginning. This figure shows the potential fuel savings, in some cases up to 19%, that can be obtained and in many instances these have been combined with reductions in the engine-out emissions. Many scientific publications have been produced from the results of this work including SAE, International Conference on Liquid Atomisation and Spray Systems and the journal Experiments in Fluids.

Such was the success of the HOTFIRE work right from that start that it has already led to a joint applied research project between Lotus Engineering and Siemens VDO (Now Continental Automotive) on a multi-cylinder version of the same engine, incorporating the advantages of the centrally-mounted injection system. The objectives of this programme were to build a mild hybrid vehicle for low CO_2 emissions, while maintaining an enjoyable driving experience from a C-segment car without compromising performance of the vehicle. The engine was designed and built by Lotus Engineering, while the injection and engine management system was from SVDO. The technologies in this project were presented at the Frankfurt Auto Show in September 2007 and as it nears its conclusion it will undoubtedly be featured in a future proActive.

As for what's next with the optical engine work with Loughborough, the recent announcement confirms the importance of the relationship and the research within Lotus' work on developing cleaner engines and vehicles. Discussions are underway as to how the research can extend into associated areas using the facilities and equipment developed in the original project. The potential is there to investigate pressure charging, bio-fuels and EGR (Exhaust Gas Recirculation) and their effects on tailpipe emissions and fuel economy. With the high-technology optical access techniques employed, it is certain to keep Lotus at the forefront of combustion research.

Source: Graham Pitcher, Lotus Engineering



Lotus introduces ‘Safe & Sound’ Hybrid

> “The popularity of hybrid and electric vehicles is increasing dramatically across the globe”

Electric and hybrid vehicles, a favourite choice of the environmentally conscientious have recently come in for criticism from a constituency that doesn’t drive: the blind.

Due to the lack of noise from hybrid vehicles at slower speeds when running on electric power, blind people say they are a hazard to those who rely on their ears to determine whether it is safe to cross the road or walk through a car park. In response to this, Lotus Engineering has developed technologies to synthesise external sound from electric and hybrid vehicles to counteract what is seen as a growing dilemma facing pedestrians.

The problem affects not only the visually impaired, but all pedestrians on a daily basis. Whether wearing earphones or simply not paying enough attention to the roads, there is a potential danger of being struck down by the near silent-electric and hybrid vehicles. And this danger is not just confined to the side of the road. Possibly even more dangerous is the impact that hybrid vehicles have on cyclists, who believe they are safe from threat until they suddenly realise a vehicle is inches away.

This issue is not entirely new and concerns were expressed some years ago when virtually silent electric trolley buses replaced trams in some US cities, meaning that pedestrians, familiar with the noise of tram wheels on rails would not hear the much quieter buses approaching. For the same reason, commercial vehicles have been using external noise systems for some time. Buzzers, beepers and synthesised voice systems are regularly heard when reversing to warn pedestrians.

The popularity of hybrid and electric vehicles is increasing dramatically across the globe and the UK is one of the top five global hybrid electric vehicle markets. The increased acceptance of greener vehicles such as hybrids and electric vehicles is something to be encouraged; after all they have an important role in improving fuel economy and reducing greenhouse gas emissions. The currently highlighted lack of sound at low speeds, leading to issues of pedestrian safety, should not overshadow the importance of these vehicles and the issue itself is something that can be overcome as Lotus Engineering has now demonstrated.

Lotus Engineering has developed technologies to synthesise external sound from electric and hybrid vehicles

Lotus introduces ‘Safe & Sound’ Hybrid

> “The approach of creating a beep or some other warning noise is problematic mainly as this may not be recognised as a vehicle”

The solution that Lotus has devised is a reapplication and development of its Sound Synthesis technology. This is a part of the Lotus suite of patented active noise cancellation technologies which comprise three main systems, each of which can be used individually or in combination.

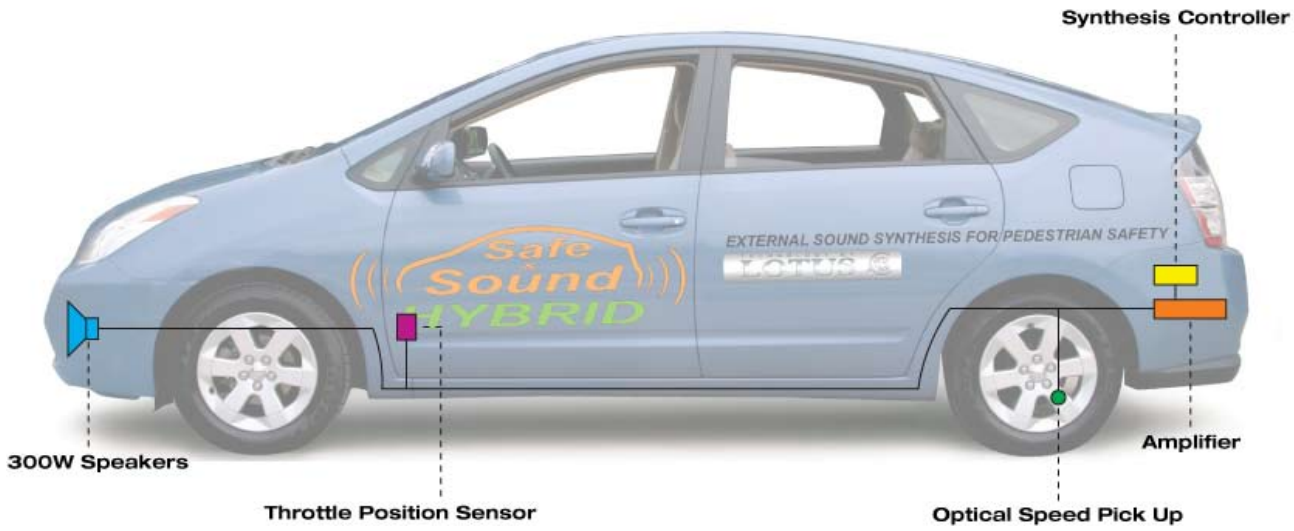
The first two systems are Active Road Noise Cancellation (ARNC) and Engine Order Cancellation (EOC). Both of these look to reduce noise levels in the vehicle cabin, particularly at frequencies that are audibly unpleasant. In the case of road noise, the system reduces noise levels at frequencies below 250Hz whereas EOC tackles harmonic frequencies generated by ignition events in the engine.

Input signals from the engine (for EOC) or sensors mounted to the suspension system (for ARNC) are fed into the electronic controller, as are sound signals, measured by microphones located in the cabin. The software algorithms of the controller then calculate what sound is needed to provide cancellation and the speakers of the in-car entertainment system are used to put this into the cabin. All this takes just a few hundredths of a second and repeats and adapts constantly through the complex control system, seamlessly and instantaneously adapting to changes in speed or road condition. Other sound in the vehicle such as the audio system and speech are not interfered with or cancelled. The result is a quieter, more pleasant cabin.

The third system is sound synthesis, the purpose of which is to enhance the sound in the cabin. The control system uses engine speed signal, a throttle position sensor and the in-car entertainment system to add sound. In this way a car could be made to sound sportier or be given the pleasing sound characters of, say, a flat 6 or V8 engine. Coupled with EOC and ARNC, the interior sound in the cabin can be tuned to enhance the driving experience and match the brand attributes of the vehicle.

It is this third system that forms the basis of Lotus’ solution to pedestrian safety, showcased on its ‘Safe & Sound’ hybrid technology demonstrator. The system has been adapted to provide external sound synthesis.

The Toyota Prius, one of the leading hybrid vehicles, was used to demonstrate the sound synthesis application and compensate for the lack of powertrain noise emitted by the vehicle when running it on an electric motor. What has resulted is the same environmentally-conscious hybrid vehicle without the potential danger to pedestrians and cyclists.



The approach of creating a beep or some other warning noise is problematic mainly as this may not be recognised as a vehicle. Indeed an anecdotal story exists of one manufacturer which made the electric vehicle emit a beeping noise that was virtually indistinguishable from the sound of a pedestrian crossing. Intuitively an engine noise is today the most recognisable sound that reliably tells anyone that a car is approaching.

Whereas the interior sound synthesis system uses a signal from the speed of the engine, in the case of the hybrid operating on its electric motor, the engine is not operating. Therefore an optical pickup was attached to the rear wheel to determine vehicle movement speed rather than engine speed. An alternative route would have been to take a motor speed signal from the powertrain control unit.

A waterproof 300W loudspeaker system was positioned adjacent to the radiator to ensure the sound emanated from the front of the vehicle. The vehicle speed is tracked and, when the car is operating on the electric motor only, throttle and speed-dependent synthesised noise projects a realistic engine sound in front of the vehicle. This noise is virtually inaudible inside the vehicle. If the hybrid’s engine starts operating, at higher speeds or throttle demands or lower battery levels, the control system automatically stops the external synthesis. When the powertrain control system switches the car back to running on the electric motor only, the synthesis controller instantaneously sets the system running again. It is all completely automatic and imperceptible to the driver.

Lotus introduces ‘Safe & Sound’ Hybrid

In order to generate the engine noise, recordings of a suitable donor engine were made and analysed to establish the dominant frequencies at different engine speeds. These frequencies are then entered into the synthesis controller in the form of a ‘voice’ which outputs the sound through an amplifier and on to the loudspeakers. Further fine tuning is achieved through varying the output volume dependent on throttle position to replicate that of a conventional powertrain setup.

The resulting ‘Safe & Sound’ Hybrid demonstrator vehicle clearly demonstrates the benefits of Lotus sound synthesis technology in improving pedestrian safety. It has however raised further opportunities of what such a system can offer and exactly the best way to implement them. One potential avenue for future research is defining the optimum sound to emanate from the vehicle. For this project, the most effective noise was the sound of an engine, as it is recognisable as the sound of a moving vehicle.

But with the increasing popularity of electric and hybrid vehicles, maybe different synthesised sounds could be the best compromise between providing a warning to pedestrians whilst minimising unnecessary noise in urban environments. Similarly, it has already created debate within Lotus as to whether the vehicle, when stationary but ‘running’, should be synthesising external sound. There is no technical issue either way, it just comes down to what is deemed the best balance between giving prior warning of a vehicle that might imminently move and minimising noise levels from stationary vehicles.

What is certain is that the system has great potential to address one of the issues facing hybrids and EVs and is yet another novel application of Lotus’ active control expertise.

Source: Matthew Reed, Lotus Engineering

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