proActive

The official industry newsletter of Lotus Engineering

Issue 18
January/February 2007

Creating the dynamics experts of the future

BMW, PSA eye 2-litre engine JV

Welcome

Welcome to proActive 18. In this issue, we take a look at the future of driving dynamics. It is a complex picture since advancements in both technology and motoring will have a big effect. New vehicle, chassis and safety technologies all influence the behaviour of vehicles. Alternative powertrains – hybrids, electric – all pose new challenges. Future driving conditions – much greater congestion, greater restrictions on speed and so on – inevitably affect how we use our cars. The goal is still to create a pleasurable driving experience.

After discussing some of these issues facing the industry, we also take a look at just a few areas of technology and research on which Lotus Engineering is working in driving dynamics.

To ensure that Lotus and the industry can keep advancing its technology and techniques, the industry needs the people to do it. A continued flow of new engineers, with the necessary training and understanding of vehicle dynamics is important. Lotus has successfully teamed up with Kingston University to help develop these engineers for the future. Paul Brandon of Kingston explains this collaboration.

Driving dynamics and driving pleasure have an important role in consumer purchasing decisions but there are many other important factors. In the current climate, green issues and environmental impact are playing an increasingly prominent part. Interchange looks at the changing impact of these on buying habits.

Nigel White, Executive Engineer – Vehicle Dynamics

Nigel White

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US: Saturn finally scoops a COTY award

Saturn general manager Jill Lajdziak had good reason to smile at January's Detroit Auto Show – her company's new Aura sedan scooped the North American Car of the Year award, the first time Saturn has won the prize in the 16 years of its existence.

Indeed, the award is a sign that Saturn is finally starting to produce products worthy of its high-quality dealer network. The GM division has been criticised for producing bland cars, and failing to hit the hot sectors such as SUVs, minivans and crossovers.

Saturn's Jill Lajdziak with the COTY award-winning Aura

Lajdziak admitted GM had considered shutting the brand down over the past few years: *"It was touch and go for Saturn – but what saved us was our dealer network and our focus on the customer."*

Saturn also turned to GM's European operations for product development – the Aura is based on General Motors' Europe's Opel/Vauxhall Vectra; the Saturn Sky coupé was derived from the GME Lightning concept car and future Saturns based on the Astra and Corsa are under development. The Vue SUV was developed by GM-Daewoo in Korea.

"Our efforts are paying off," Lajdziak said.

The Aura won the NACoTY award because of a combination of performance, specification and build quality. A hybrid version will be added to the range later this year. It beat the latest-generation Toyota Camry in the final voting – a major achievement as Camry is America's best-selling car.

GM also won the North American Truck of the Year award with the Chevrolet Silverado large pick-up truck.

Source: just-auto.com

GERMANY/FRANCE: BMW, PSA eye 2-litre engine JV

BMW Group and PSA Peugeot Citroën have signed a letter of intent to consider extending cooperation on petrol engines which sources say will be around two litres in size.

In a joint statement, the two automakers on Monday said they had *"agreed to extend their successful cooperation in the field of petrol four-cylinder engines. They will jointly conduct a feasibility study concerning a new family of engines with advanced technology features aimed at delivering excellent power and torque characteristics combined with reduced fuel consumption and CO_2-emissions.*

"If the study confirms the expected technological, industrial and financial benefits, the two companies intend to enter into a joint development project."

BMW and PSA are planning a second engine JV

A BMW spokesman in Germany declined to provide any more details but sources close to PSA Group said suggestions the engine family would be larger, around two litres in capacity, four cylinders and not destined for the Mini would not be wide of the mark.

The sources also said a more detailed announcement was expected early in 2007 as such early deliberations typically take about three months.

This extension upwards is significant, as BMW is famed for its innovative engine technology, and it now seems certain it will be sharing the smaller petrol engines for its core BMW range with PSA.

BMW's current I4 petrol engine line is made at Hams Hall near Birmigham in England, home to some of the engines developed under the current PSA-BMW cooperation agreement that recently developed a family of 75-175hp 1.6-litre petrol engines for the redesigned Mini plus Peugeot and Citroën vehicles.

In this case the two companies produce the engines separately. Peugeot produces its needs – for models such as the Peugeot 207 – at FranÇaise de Mécanique in Douvrin near Lille, France, while BMW prefers its UK plant, mainly because its versions of the engines are destined exclusively for the Mini, built down the road in Oxford.

BMW originally set up Tritec Motors in Brazil, a joint venture with DaimlerChrysler, to produce small engines for the Mini. It no longer sources any engines from there, having switched production to Hams Hall.

The larger BMW I4 engines made in the UK have technology such as Valvetronic, which replaces the traditional throttle butterfly with electronic variable valve timing and opening to control engine speed.

Source: just-auto.com

US: Ford unveils fuel cell hybrid with plug-in capability

Ford has attempted to trump GM's Chevrolet Volt plug-in with a hybrid electric plug-in version of the Edge crossover that combines a hydrogen fuel cell generator with lithium-ion batteries.

The vehicle is built on a flexible powertrain, an architecture that will enable Ford to use new fuel and propulsion technologies as they develop without redesigning the vehicle.

"This vehicle offers Ford the ultimate in flexibility in researching advanced propulsion technology," said Gerhard Schmidt, vice president of research and advanced engineering at Ford. *"We could take the fuel cell power system out and replace it with a downsized diesel, gasoline engine or any other powertrain connected to a small electric generator to make electricity like the fuel cell does now."*

The new HySeries Drive powertrain uses a real-world version of the powerplant envisioned in the Airstream concept unveiled in January at the 2007 Detroit Auto Show.

Ford Edge crossover concept vehicle

The plug-in hybrid is powered by a 336-volt lithium-ion battery pack at all times. The vehicle drives the first 25 miles each day on stored electricity alone, after which the fuel cell begins operating to keep the battery pack charged. This provides another 200 miles of range for a total of 225 miles with zero emissions.

When the battery pack is depleted to approximately 40%, the hydrogen fuel cell – supplied by Ballard – automatically turns on and begins generating electricity to recharge the batteries. Like a conventional vehicle, the Edge hybrid will go until it runs out of fuel – in this case via a 350-bar hydrogen tank that supplies 4.5kg of useable hydrogen.

A screen helps the driver tell how much battery power is being drained, promoting efficient driving

The HySeries Drive name is derived from the powertrain's structure: a hydrogen fuel cell-powered series hybrid drivetrain. This highly innovative approach reduces the size, weight, cost and complexity of a conventional fuel cell system by more than 50%. It also promises to more than double the life of the fuel cell stack.

This flexible powertrain architecture enables the use of new fuel and propulsion technologies as they develop and become available without the need to redesign the vehicle and its control systems.

Ford said that, certainly, many significant technical hurdles need to be overcome before a vehicle such as this Edge can become a reality. Fuel cell vehicles remain expensive, costing millions of dollars each. And the single biggest hurdle to plug-ins remains the cost of lithium-ion batteries.

Source: just-auto.com

UK: Steelmaker develops 'fluxless laser brazing'

Steel maker Corus has developed *"fluxless laser brazing"*, a new and robust process for joining steel to aluminium during automotive production line assembly.

The new technique was developed in Holland to support the automotive industry's increasing use of multi-materials in new car design and manufacture, as a way of reducing weight and improving CO_2 emissions.

Although reducing weight to improve CO_2 emissions remains one of the main drivers in the global automotive industry, the need to lighten weight is balanced against the need to keep manufacturing costs down. Thanks to its performance and cost benefits, there is little doubt that steel will remain the material of choice for main vehicle body structures in volume car production, Corus said, noting that designers are substituting steel for aluminium for specific applications, such as the bonnet and roof, where advantages beyond weight reduction, such as weight distribution for optimum ride and handling, can be achieved.

> **"Controlling the heat input using laser-based welding techniques has been one way of reducing the thickness of this inter-metallic layer"**

Until now though, the welding of steel to aluminium has been a complicated process and one that poses specific challenges for vehicle manufacturers. For example, when the two different materials are welded together, it results in a thick inter-metallic layer, which can result in a brittle and weak weld joint that is clearly not suitable for any automotive application. Controlling the heat input using laser-based welding techniques has been one way of reducing the thickness of this inter-metallic layer. However, traditional laser welding methods require the use of a salt-based flux to enable a joint to be created. This is not without problems, as a salt-based flux is more prone to expose the joint to corrosion.

The new process removes the need to apply a flux during the welding process which, Corus thinks, will help take significant costs and time out of the manufacturing process. In addition, removing the salt-based flux also removes the potential source of weld corrosion.

The fluxless laser brazing process works by applying an aluminium-based filler wire to create a weld on the aluminium side of the joint. The molten filler metal then 'wets' the steel creating a 'brazed joint' on the steel side of the weld. Importantly, tests have shown that this new technique creates only a very thin inter-metallic layer making it possible to create joints that are, in some cases, stronger than the base materials themselves.

A Corus spokesman said: *"We believe our new welding process is ideally suited to joining aluminium components, for example a roof, into a steel body-in-white, offering vehicle manufacturers further options for saving weight beyond the use of advanced high strength steels."*

Source: just-auto.com

BELGIUM: EC wants 10% biofuel by 2020

The European Commission (EC) has proposed that biofuels make up a minimum of 10% of all transport fuels by 2020.

The move its part of the EC's *"Renewable Energy Roadmap"* that is integral to its new energy policy for Europe.

The proposals will be debated in the spring by the European Council. A proposed legislation package will include legally binding targets, but each member state will have the freedom to determine the best renewable energy mix for its own country.

The European Union (EU) started working towards a target of 12% share of renewable energy in its overall mix by 2010, but the figure looks unlikely to exceed 10%, despite the fact that renewable energy consumption has increased by 55% since then.

The roadmap also emphasises the need for the coordinated development of biofuels throughout the EU.

"It is particularly important to define these targets now, as manufacturers will soon be designing future vehicles that will need to run on these fuels," said the commission in a statement.

It added; *"While biofuels are more expensive than other forms of renewable energy today, they are the only way to significantly reduce oil dependence in the transport sector over the next 15 years."*

Source: just-auto.com

US: The ZAP-X crossover electric car

Automotive pioneer ZAP has announced plans to display Lotus Engineering's advanced APX concept car at the North American Dealers Association (NADA) annual meeting and exhibition, scheduled to take place the beginning of February, confirming their choice to move ahead using Lotus' revolutionary platform and body structure design as the basis for the development of the high performance electric ZAP-X.

ZAP and Lotus Engineering will begin the first phase of an engineering project to use the British consultancy's APX *("Aluminium Performance Crossover")* as a basis for designing a production-ready electric all-wheel drive crossover high performance vehicle for ZAP in the US market.

> *"Lotus Engineering's APX is a world-class innovative concept and was developed to showcase real solutions to new challenges facing the automotive industry"*

A combination of the lightweight aluminium vehicle architecture, a new efficient drive and advanced battery management systems is intended to enable a range of up to 350 miles between charges, with a rapid ten-minute recharging time. An auxiliary power unit is planned to support longer distance journeys.

Lotus' APX's conventional gasoline V6 engine will be replaced by revolutionary in-hub electric motors, delivering 644 horsepower in all wheel drive mode, theoretically capable of powering the ZAP-X to a potential top speed of 155mph. A new strong, lightweight and highly efficient structure based on the Lotus technology is planned to give the car a very attractive power-to-weight ratio.

Steve Schneider, CEO of ZAP, said: *"Lotus Engineering's APX technology demonstrator vehicle is a perfect fit for our plans to introduce a full product portfolio of electric cars. Due to the initial design by Lotus, our cost and time to production will be significantly reduced. We believe that the ZAP-X will become the most advanced, most practical and most appealing flagship electric vehicle to date and will revolutionise the industry providing the driver with the enjoyment of a sports car and the practicality of an SUV."*

Mike Kimberley, CEO of Group Lotus plc, said: *"Lotus Engineering's APX is a world-class innovative concept and was developed to showcase real solutions to new challenges facing the automotive industry. So it's very satisfying that ZAP's proposed new model will make use of a great deal of the APX concept's advanced body structure and chassis technology. The bringing together of these next-generation vehicle technologies represents another significant step forward for automotive technology."*

The APX showcases Lotus Engineering's Versatile Vehicle Architecture technology, combining lightweight aluminium vehicle architecture with exceptionally strong and stiff structural rigidity, as well as lower manufacturing investment requirements. Having first been shown to the world at the Geneva Motor Show in 2006, the APX concept has won the 2006 European Aluminium Awards in the *"Transport and Automotive"* category.

Lotus Engineering's APX technology demonstrator vehicle

The innovative placement of the powertrain leaves the space previously occupied by the conventional engine and drivetrain for additional battery capacity and amenities, making it a very consumer-oriented electric car concept. These design features will give the ZAP-X crossover the structural strength, and potentially storage and range, that no electric vehicle has yet publicly achieved.

The development programme is proposed to be managed from a new centre of excellence for research and development of environmentally-friendly vehicle designs and technologies. Engineering input will come from Lotus Engineering Inc, and the British technology consultancy's other R&D centres in the UK, Malaysia and China.

Source: Lotus Engineering

Lotus Brands Hatch world record

Lotus owners are renowned for their dedication to the marque, and they can often be found enjoying their cars on a twisty country road in conditions lesser sports cars would shy away from. So when Lipscomb Lotus, the new dealer in Maidstone, Kent, England came up with the idea to organise not only the largest gathering of Lotus cars, but also the biggest ever meet of any marque in the world, it was guaranteed to be a success!

A crisp January morning was the setting for the Guinness World Record attempt and as upwards of 200 cars gathered at the new dealership, their owners fuelled up with a hog roast and admired Lotus icons such as the Lotus Cortina and Ayrton Senna's Lotus Type 99 in Lipscomb's fantastic new showroom.

The cars then made their way in convoy to Brands Hatch, a racetrack forever linked with Lotus' Formula One success and host to the day's activities. By now, over 300 cars were present including immaculate Guigaro-designed Esprits and even a few very rare Lotus Sunbeams.

Preparing for the off

The Brands Hatch Indy circuit quickly became the site for the largest and one of the most varied Lotus gatherings in the history of the marque. With the queue of cars now stretching one full lap of the track it became apparent that we had smashed the existing record achieved by 247 Mazdas in America. Four laps of the circuit then followed with the natural amphitheatre in which Brands Hatch sits echoing to the sound of Lotus Twin Cams and V8s.

> "The Brands Hatch Indy circuit quickly became the site for the largest and one of the most varied Lotus gatherings in the history of the marque"

The world record in full flow

The final count of Lotus vehicles participating in the record attempt was 311, an extraordinary feat achieved by a variety of owners who are all passionate about their cars.

As the track emptied the journey home commenced with the cars still in convoy. It's only when reflecting back on a fantastic day where cars from the last 50 years of Lotus set a new world record that you realise just how special the cars and their owners really are.

Source: Kieran Harper, Lotus Cars

Green issues and corporate responsibility dictate buying habits

What is the biggest influence in the car-buying decision process? Price? Proximity of dealership? Brand awareness? Colour? There's increasing evidence that a company's record on corporate social responsibility and the environment is now racing up the ladder of tick boxes.

Jeremy Barnes, group manager for product communications at Mazda North American Operations, speaking at the 2007 motor show in Detroit, said: *"When you have two products that are identical except one is cleaner, customers will generally choose the more environmentally friendly one."*

That is one of the reasons that more and more US car makers are offering vehicles that will run on E85 ethanol – and Mazda is also launching its first hybrid, the Tribute, later this year in the US.

In the UK, new research from Gilbran, an automotive real estate company, reveals that Britons would be willing to pay up to GBP506 more for a new car if this extra money were invested in funds to make the vehicle carbon neutral and to recycle it at the end of its life.

The findings come on the back of the EU End of Life Vehicles Directive, which came into effect on 1 January, and it suggests that car manufacturers may not be forced to pick up the entire cost of recycling cars at end of life themselves and that consumers may be more willing than previously thought to accept increases in car prices as a result.

The research suggests that this would provide GBP1.2bn (based on annual UK new car sales of 2.4m) in extra revenue for car manufacturers to spend on green projects and recycling schemes.

The study found that almost one in five (19%) of British drivers said they would not be willing to pay any more money to ensure their cars were carbon neutral and recycled at the end of their lives.

But an equal number said they would be willing to pay more than GBP1,000 extra for their new car, if the money were invested in ecological schemes with more than one in ten (11%) prepared to pay an extra GBP1,500 over the current list price.

"This sends a clear message that drivers are willing to invest more to ensure they reduce the impact of their motoring on the environment but they will equally expect to see viable schemes from manufacturers if they are to feel that their largesse is not being wasted," said Gilbran managing director Nigel Smith.

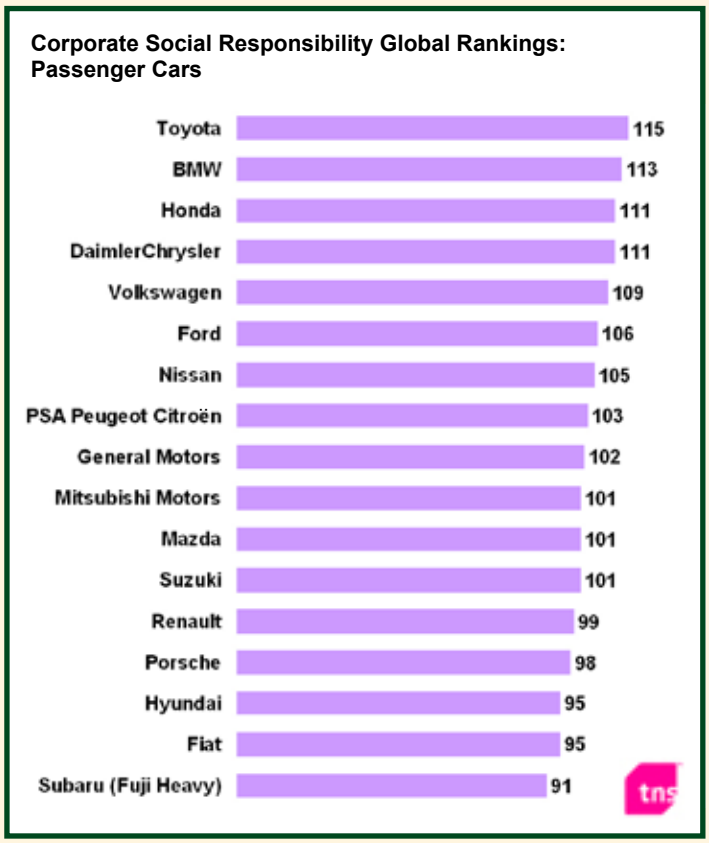
A far more wide-ranging survey into Corporate Social Responsibilities (CSR) by TNS Automotive, a global market research and information group, interviewed more than 18,000 people covering 80% of the world's car market.

It found that CSR has become a focal point for the automotive industry as the general public has become more concerned about how corporations deal with environmental issues and give back to society from which they profit.

This applies to environmental and social issues such as:

- alternative fuels, ethanol, bio-diesel, and hybrids;
- depletion of natural resources such as fossil fuels;
- traffic accidents – a leading cause of death globally;
- traffic congestion and pollution;
- employment issues – generating jobs and ensuring the safety and welfare of employees and their families;
- contribution to cultural events, arts, and sciences.

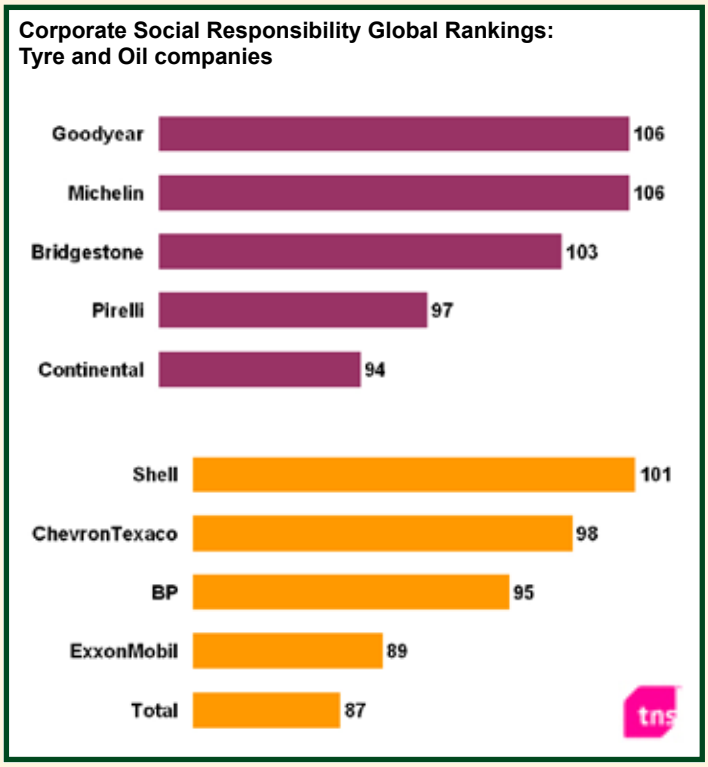
The survey found that Toyota ranks highest globally for Corporate Social Responsibility. In Europe, the leader is BMW, followed by Volkswagen. BMW also ranks highest in Italy and Spain and second-highest in Germany, while Toyota ranks highest in Japan, Thailand, the Philippines, and Korea and Honda is the highest ranking in the US, UK and Indonesia.



The survey also extended to tyre and fuel companies. Goodyear and Michelin both rank highest among tyre companies, with Goodyear performing better in Asia and the Americas and Michelin performing better in Europe, especially in France where it ranks highest among all automotive companies.

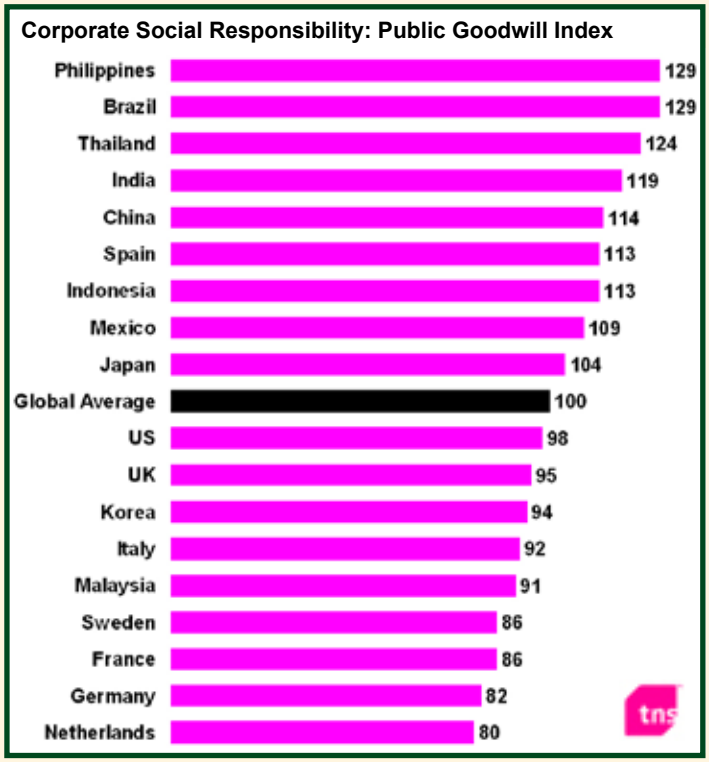
Among oil companies, Shell ranks highest globally and highest among all automotive companies in China.

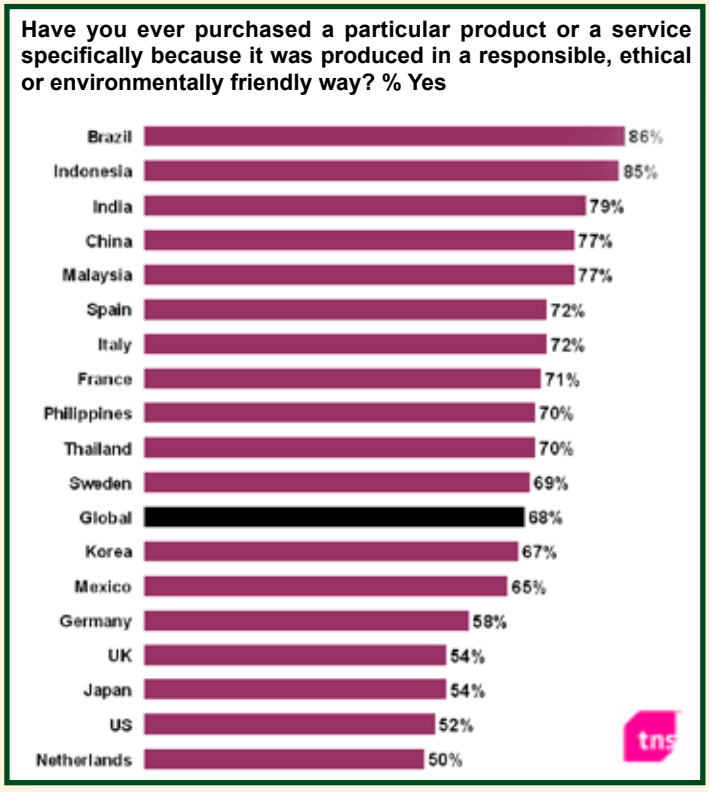
In Europe, BP ranks highest among the oil companies, but rates lower in Asia and the Americas. (see chart below).



"In Europe, BP ranks highest among the oil companies, but rates lower in Asia and the Americas"

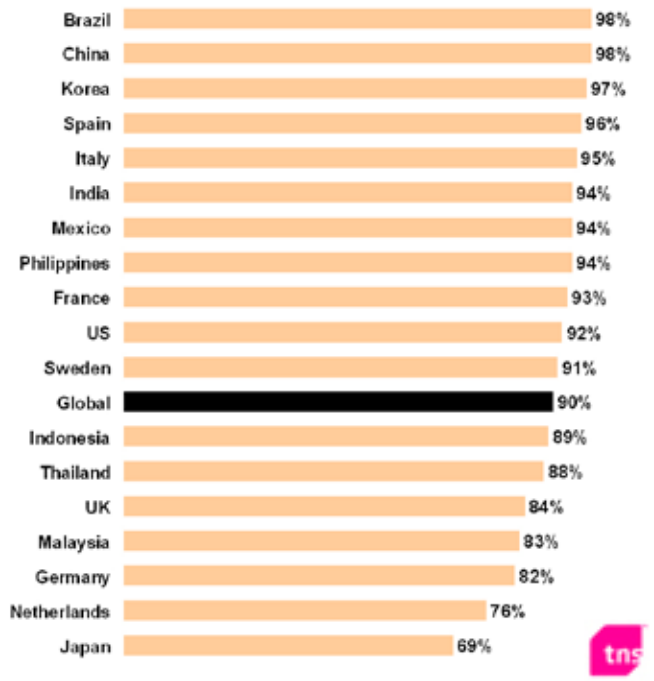
It is probably no surprise that emerging markets rate car companies higher on Corporate Social Responsibility as these companies are often seen to be contributing to the social and economic development of their countries while in European markets, automotive companies are rated poorly for job generation and for their performance on environmental factors (see chart below).



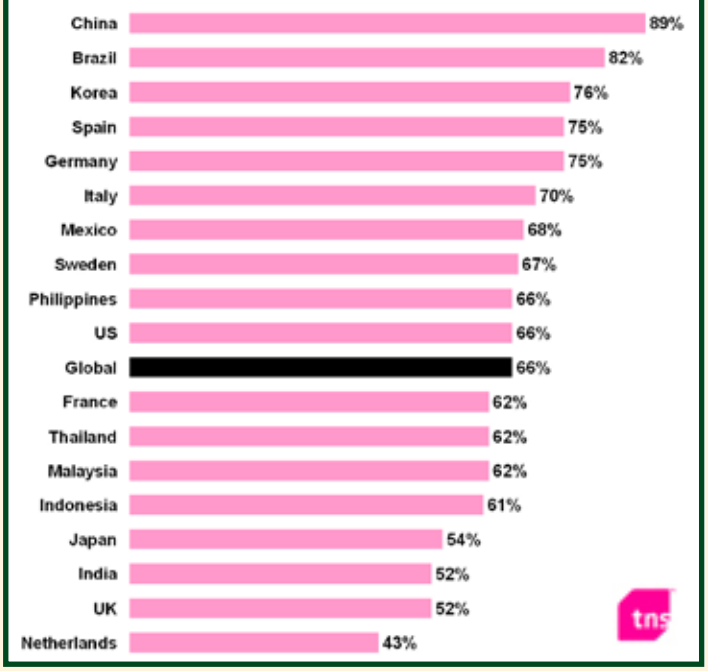


There is another trend emerging. The growth of hybrid and dual-fuel vehicles is leading to a situation where people will choose a car by the fuel that suits them, just as they would choose a red or a blue car, said Mazda's Barnes.

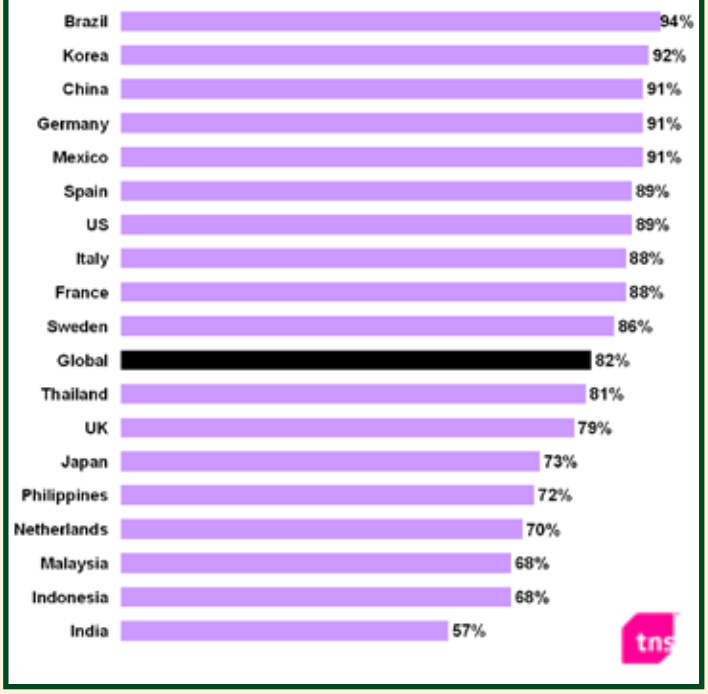
Would you be more likely to purchase a product or a service from a company that you believe follows responsible and ethical business practices? % Yes



Have you ever refrained from purchasing a product or a service because you believe the company fails to follow environmentally friendly or ethical business practices? % Yes



Would you be more likely to refrain from purchasing a product or a service because you believe the company fails to follow environmentally friendly or ethical business practices? % Yes



This is already the case in countries like Brazil where owners of some cars can choose to fill up on ethanol or regular petrol, depending on which is cheapest. Suppliers Delphi and Bosch have both developed fuel sensors for Brazil which detect whether you have just filled up with ethanol or petrol and adjust the engine management system automatically.

As sales of big US-only SUVs fall, sales of other vehicles are expected to increase. Paul Ballew, executive director for global marketing industry analysis at General Motors, said: *"We expect strong sales of mid-size SUVs in 2007 and substantial growth in crossover models."*

Crossovers, 4x4 models with more sporty saloon-car styling, featured on almost every manufacturer stand at this year's North American International Auto Show in Detroit. Ballew added: *"People want more versatility from their vehicles and while we saw a slow down in SUV sales in the US as fuel prices rose last year, the market is picking up again."*

Former Nissan UK chief Bill Bosley, now back at Nissan North America, said: *"We have seen a softening in sales of large SUVs but people are definitely going for the crossover models because they want something more flexible – a cross between a 4x4, a people carrier and a saloon car."*

So, if you want a trend, how about the best of both worlds, a flexible vehicle with a flexible fuelling system?

Source: Interchange

Creating the dynamics experts of the future

One of Kingston University's key strategic aims is to ensure that the courses offered fit with the needs of industry. Degrees in Automotive Engineering had been offered for 15 years and degrees in Motorcycle Engineering for ten years, but in 2000 Kingston started discussing the possibility of extending its automotive provision to include more Performance Engineering, such as Motorsport. After thorough market research, it became apparent that there were several degree level course covering general Motorsport and only one at postgraduate level. This specialised in Motorsport Management. However, there were no courses set up to further knowledge in the practical and theoretical engineering required for performance cars, either for the road or race track. As a result, Kingston decided to further explore the possibility of developing a course specifically tailored to the dynamics of performance vehicles.

Industry has made it clear that it does not want new recruits who know the theory but are unable to apply it. They want applicants who can be effective from day one. In order for the course to be relevant and for Kingston to produce graduates with the best possible chance of future employment, it was decided that there had to be a significant level of practical/hands-on experience to complement the necessary theoretical studies. It was also vital that the course covered the essential skills that industry would expect in the area of vehicle dynamics. To ensure both of these elements were fulfilled, the course needed to be very closely linked to industry – not just in name but also in its delivery and development. In short, an industrial partner was essential. The natural choice of partner for us was Lotus, a company regarded as world leading at vehicle dynamics. In 2001 Kingston went to talk about our vision. We were very well received and Lotus was keen to work with us – if not they could see we were prepared to adapt to the needs of industry and not be as rigid as some of the *"older institutions"*. To further show Lotus' support for the course, they provided Kingston with a new Exige. Time was then spent modifying the course content to closely reflect what industry needed and addressing how the practical elements would be delivered.

A high level of cooperation between industry and academics

The Kingston/Lotus course illustrated the need for a high level of industry/academic collaboration. This has since been reinforced by the workforce development plan commissioned by the Motorsport Industry Association in 2003, which highlighted the lack of practical ability in graduates applying for jobs.

The rationale for the course was to develop a new breed of well educated engineers able to make informed judgements, leading to faster development times and improved products thus maximising the potential of performance vehicles at all levels within the industry.

The course itself is structured into eight taught subjects:

- data acquisition;
- chassis characteristics, suspension systems and simulation;
- motorsport powertrain design;
- practical racecar preparation and set-up;
- driver training;
- advanced materials;
- electronic control systems;
- racecar aerodynamics.

The Kingston Exige – classroom on wheels

25% of these, the racecar engineering and driver training, are taught exclusively at Lotus (Hethel), the rest being delivered at Kingston. This course structure is currently unique in the UK (possibly Europe).

An aspect of the course which is particularly attractive to the students is the practical training by Lotus personnel on static set-up, suspension kinematics and compliance measurement, damper construction, measurement and testing, dynamic rig testing and active technologies. The cherry on the top is that the students are provided with driver training to ensure they are competent to perform the necessary on-limit manoeuvres required to evaluate the transient stability or dynamic response of the Kingston Exige.

The analogy put to students is one of riding a bike. In theory, it is possible to tell someone how to ride a bike. However, when they first try it, the likely outcome is that they will fall off. It is only after practice that it all makes sense. The same is true for this course. Give the students a car that has been set up for a quick turn in response and they are unlikely to be able to tell if it is a damper, spring or roll bar change, even though they have had the theory. By the end of the week, after all the practical training, it all fits into place and you can see the students having that *"Eureka moment"*.

Students come to Lotus in blocks of five and spend 60 hours there carrying out the required activities and assessment. Lotus personnel also come to Kingston to give guest lectures on the latest developments in other areas, such as powertrain, control and vehicle dynamics.

At the end of the taught subjects, the students then take on a substantial project that equates to 600 hours of work. These projects are industrially led and are written in such a way that the final outcome is beneficial to the company. These projects are supervised by a nominated person within the company and by an academic from Kingston. Previous projects at Lotus have included work on damper characterisation, rear wheel steer control strategies and development of the Suspension Kinematics and Compliance Measurement System (SKCMS). Projects with other companies include, tyre modelling (Dunlop Motorsport), suspension development (Radical) and new torsional test methodologies (Lola).

Formula Jedi racecar prepared by Kingston Students

The joint research is mutually beneficial. As an example, the initial work on damper characterisation has been continued by staff at Lotus/Kingston and led to a paper being presented at the Vehicle Dynamics Expo 2006 and one being prepared for a SAE conference this year.

In order that the students get the full benefit of the course, numbers are limited to a maximum of 15 per year. Any more than this and the practical content would have to be reduced.

Entry requirements for the course are a good first degree or relevant industrial experience. Over the four years that it has run, there has been a wide mix of students from the UK, China, India, Australia and Europe. The age profile of the students range from those who have just completed their first degree at 21 to those currently in industry looking to further their knowledge at 41.

With the course now in its fourth year, previous students have gone on to a variety of jobs in the performance automotive or motorsport sectors at companies including Dunlop motorsport, Bentley, IAV, A1 GP, Mercedes and Jaguar.

With the course titled *"motorsport Vehicle Dynamics"*, almost all of the students come on to the course wanting a career in motorsport. The students' perception is that motorsport is a sexy industry, much more so than automotive. Interestingly, after the students have spent a week at Lotus, around 75% of them come back to Kingston and strongly express how much more varied and challenging they now believe the automotive industry to be.

Kingston is very proud of its collaboration with Lotus and looks forward to this relationship going from strength to strength.

Paul Brandon, Kingston University

Driving pleasure for future vehicles

Predicting the future is perhaps best left to politicians, stock market analysts and weathermen! However we can, with some confidence, extrapolate which future technologies may feature on our vehicles and therefore the potential outcome for driving dynamics.

As drivers, we are faced with the mid-term prospect of ever increasing traffic congestion and increasing speed controls that are at odds with driving pleasure. For those of us who are responsible for delivering attributes that encompass and enhance driving pleasure, how do we include this developing scenario with ever more stringent legislative driven design criteria that increases vehicle size, mass and complexity? It appears to be a daunting task.

However, we have, as an industry, been very successful. Current vehicles exhibit greater capability than ever before – with higher road speeds, cornering capability and brake performance – and yet they are safer, more comfortable, reliable and affordable. The range of performance vehicles on sale has never been so extensive and potential buyers for these vehicles are spoilt for choice. Coupled with higher levels of affluence and greater aspirations, these buyers will continue to support a growing market for niche vehicles and performance derivatives of mainstream products.

Current vehicles exhibit greater capability than ever before

Coupling all of these factors, we have a wide range of *"Track day"* events available to drivers who want to fully explore the performance envelope. Driving enthusiasts have never been so well catered for and we have a very mature driver-focused performance market. Indeed numerous companies, including Lotus, are offering *"hardcore"* track day cars.

There appears to be a paradox at present though, with external pressures seeking to control mainstream vehicle speeds and yet an expanding market desire for ultimate performance. How long this situation will continue is difficult to predict, but the next five years may prove to represent the pinnacle of traditional vehicle engineering. It is difficult to imagine future vehicles that are faster and with more cornering capability than we have at present, considering the prevailing road conditions and impending legislation that most authorities are considering.

We will continue to witness an increased use of advanced systems, and in some cases this may seemingly be at odds with driving pleasure. A clear example of this has been the adoption of early electric steer systems. Whilst there was adequate rationale for the adoption of this on some mainstream cars (reduced fuel consumption, improved assembly process etc) the systems tended to suffer from a lack of *"feel"* and poor damping. Current systems have improved enormously but it is likely to be a long time before an electric steering system provides class-leading steering feel (if at all).

Indeed, it is our experience that only one new chassis technology in the past decade has not adversely affected driver enjoyment – the fun factor – and this, we believe, is traction control. The system developed for the Elise has not detracted from driver enjoyment and yet has provided an increased level of reassurance. The key factor here is an appropriate level of complexity, intervention and a system developed with a focus upon driver enjoyment.

Without doubt, advanced systems have increased vehicle capability, but increased capability does not necessarily produce increased levels of involvement or enhance the fun factor. While the car remains an autonomous vehicle, there will always be a market need for attributes that provide for driver excitement/ enjoyment. However, it is likely that for most of us this will be at lower and lower vehicle speeds. The issue will be whether driving pleasure will remain a strong selling point in the next decade or whether the market will deviate from this due to other external factors. So perhaps the best that we can hope, or indeed plan for, is that future vehicles will, in general, be no less fun to drive than they are at present.

The next five years will herald new possibilities arising from the adoption of alternative powertrains. This will act as a catalyst for significant change in the coming decade. We currently enjoy a wide range of vehicles due to the benefits of platform sharing – and the subsequent cost reductions in design and development. Currently one platform can spawn sub-systems that are applicable across a wide range of segments. One of the key exponents of this, VWAG, is now designing/developing a greater range of performance-focused models than ever before. However, can this platform sharing continue when utilising widely differing powertrain and energy storage methodologies?

If it cannot, then the performance car segment may become further dominated by niche vehicle engineering as the main

market segments transfer across to these newer power technologies. There will be greater concentration of effort amongst the OEMs to engineer these solutions. This process may well be hastened by new emission regulations, road charging strategies and potential market dynamics and hence result in a change to the customer buying criteria.

After this transitional period, the evolving technologies surrounding the adoption of electrical power architecture may mean that performance motoring (power, low mass and dynamics = excitement) will move further away from mainstream motoring (low emissions, running costs and increasing levels of automation).

For companies such as Lotus this opens new possibilities for both its manufacturing and engineering divisions as its strives to offer more driver-focused niche vehicle solutions, and design and development expertise for increasingly complex technologies for our engineering clients.

As end-users, we may well become more polarised in our needs, if we use vehicles purely for transport or wish to remain driver enthusiasts. Despite the possibilities for performance from hybrid/electric vehicles, it is likely that most of these will be developed for economy, ease of use and commuting. True performance vehicles will remain predominantly petroleum-based for the foreseeable future, although biofuels present a green performance alternative.

The emergence of refined and powerful diesel engines and their potential integration with sports/performance vehicles has aroused a lot of discussion. These vehicles are easy to drive fast, due mainly to the accessible performance via engine torque and the potential for rapid cross-country performance. They could therefore lend themselves to a performance derivative, but this is not enough. We should also not forget that the greater engine mass potentially lowers lateral response rates, reduces cornering power and blunts braking performance. Also, although the refinement levels have improved dramatically, there is also little pleasure to be gained by revving out a diesel.

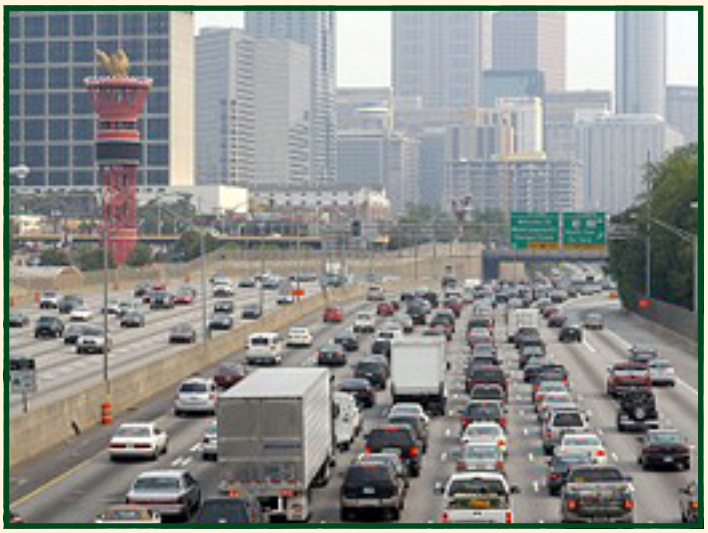
Automotive electronics and control systems continue to evolve and mature but at an increasing pace. The majority of vehicles now have a level of chassis control. Some even have active control of cabin refinement.

Lotus has been a long-term pioneer of active control of noise, vibration and vehicle dynamics. The market for these solutions is still maturing but there is no doubt that their potential will be enhanced by the introduction of greater electrical capability (via a move to higher voltage systems to support electric and hybrid powertrains).

Steer by wire technology offers numerous benefits for impact safety, packaging and cabin design but does present a number of problems for steering *"feel"*. This is important and is currently one attribute that even major OEM's continue to misunderstand even with conventional steering system.

Rear wheel steer has also failed to break into the mainstream even though there are performance enhancements that would assist with obstacle avoidance, braking and yaw stability and, of course, low speed manoeuvrability.

Advanced damping solutions are becoming more commonplace. Whether they are based upon the magneto-rheological (MR) principle or electro-mechanical operation, they are beginning to offer tangible benefits when deriving a solution to the often difficult ride/handling compromise.



Vehicles purely for transport or for driving enthusiasts?

Traction control systems (TCS) will continue to filter down onto a wide range of vehicle and be complimented by stability control algorithms. How much longer TCS remains switchable is open to doubt, but its seems illogical to offer a switch when the vast majority of drivers lack the required skills to prevent or overcome a situation that would benefit from its use. The insurance industry may take a position on this and force a change. As previously mentioned Lotus has managed to integrate a TCS system onto the Elise which has won universal acclaim for its non-intrusive but capable operation.

Noise, vibration and harshness (NVH) development of electric and hybrid vehicles has highlighted several issues with refinement. For example, with very low noise/vibration levels from the electric drive units, road noise and wind noise is more prominent. This can adversely affect the driving experience as we should not forget the part that suitable intake/exhaust noise plays in describing the character of conventional powertrains and hence perhaps the vehicle soul. This noise source is completely absent in electric powertrains and therefore presents an obvious application for the Lotus developed noise synthesis system. Whilst it is possible to produce a noise track that mimics a very wide range of engine layouts (3, 4, and all the way up to 12 cylinders), we do not have to restrict this output to convential engines 'noises'. What would you like it to sound like? How about a *Star Wars* X-wing fighter?

Lotus can also provide a solution to the road noise problems with its road noise cancellation system. This achieves broadband cancellation of low frequency road noise using the ICE loudspeakers in conjunction with accelerometer reference signals. During application development at Lotus, significant reductions in road noise levels were achieved (8-12dB) and across a wide frequency range (30-250Hz).

As an aside, recent experience at Lotus has highlighted issues with the mix of electric vehicles and pedestrian safety. This has been noticed within the workshop environment where low speed manoeuvring is almost completely silent.

Of particular note is the potential application of Lotus active valvetrain technology to vehicle dynamics. Perhaps a strange application at first instance? Well the small actuators that are used to operate each valve could form the basis for '*active*' suspension bushes. This could offer the potential for dynamic control of toe and camber. This in itself is a viable use of this technology, as we understand the influence that relatively small changes in these characteristics can have on stability, cornering power, "*feel*" and ride behaviour. As we are increasingly faced with helping our clients develop and refine their brand (and driving dynamics plays a crucial role), the tuneability that active control offers is highly attractive – if it can overcome the cost/complexity issues.

As vehicle speeds are more tightly controlled, road noise suppression will become of greater importance

Looking further into the future, we may be able to combine active bushes with a linear actuator – for vertical wheel motion. We could thereby drasticaly alter the kinematic requirements that would be needed and hence many of the packaging issues surrounding suspension design. If this were coupled with steer by wire (and the potential for independent wheel control) then complete control of the vehicle's yaw behaviour is possible.

How will this benefit driving dynamics and more specifically enjoyment? In the first instance, vehicle character will be instantly tuneable but whether this will result in more enjoyment is unlikely. The platform may become more flexible and offer more opportunities for automation, but more fun? Probably not.

Wheel tyre sizes have been evolving, but not in a direction that is sympathetic to ride comfort and road noise. Whilst there are some performance gains, this direction continues to be a concern for development engineers. Structures and bushes, as well as springs/dampers and NVH treatments, have all had to accommodate this trend. Indeed it is felt that many of today's vehicles would benefit from road noise attenuation (of sorts) because of this trend.

It is obvious that these tyres are not well suited to the developing markets and we are currently spending large amounts of time optimising alternative specifications when sharing platforms across developed and developing automotive regions. Michelin is exploring the Tweel, a completely new type of airless tyre and one that would appear to offer significant opportunities for the future.

As vehicle speeds are more tightly controlled, and therefore fewer occupants experience speeds greater that 140km/h, wind noise issues will reduce to the point that road noise suppression will become of greater importance than it appears to be at present.

So, whether we like it or not, there will be increased pressures to lower and further restrict vehicle speeds (whether within our cities and towns or on the major road networks that link them).

There will be increasing demand/expectation to differentiate products via a range of attributes. These attributes may be readily tuneable via software changes within various control strategies. Along with these control systems, hybrids and electric drives (single or multiple) will influence driving dynamics, but it is unlikely that they will increase the fun factor. Furthermore increased congestion may force dynamics engineers to inject 'sparkle' into the chassis performance in the sub 100km/h.

Difficult as it can be to predict, whatever the future holds, making driving pleasurable is a mission that Lotus is happy to accept.

Source: Nigel White

A closer look at Lotus' driving dynamics R&D

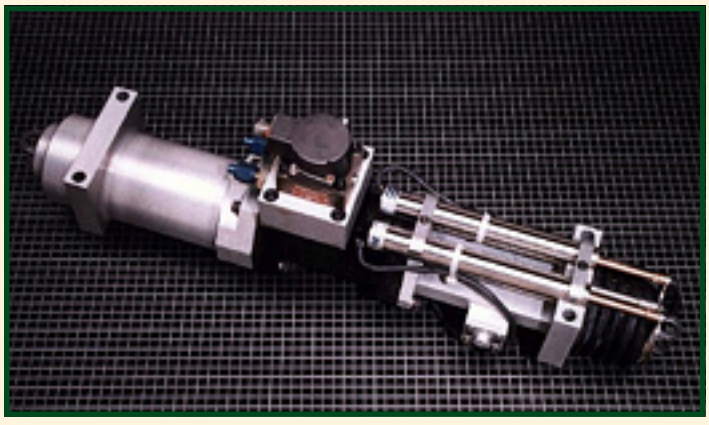
As you would expect, Lotus continues to investigate innovative solutions to enhance the attributes that make up driving dynamics. In this article, we take a look at three of Lotus' Driving Dynamics research areas: Rear Steer, Vehicle Refinement Technologies and Advanced Damper Characterisation.

Rear Steer System

Historically, one of the cornerstones of Lotus' activity has been research into active suspension, which has produced more than 70 active suspension research and development vehicles during the past 20 years. On some of these vehicles, we have investigated the integration of advanced steering methodologies and the potential benefits that these systems can offer. As the traditional line between ABS and yaw dynamics becomes blurred, it is of key importance to understand the future opportunities that may arise.

The next decade will witness the implementation of numerous active control systems in vehicles, with some examples being advanced braking, roll control, torque vectoring and steering systems. To ensure optimal control of vehicle dynamics, it is of prime importance that these systems are fully integrated and therefore act in a coordinated manner.

The current Lotus research programme will provide valuable tools for evaluating the ultimate level of performance achievable by a totally integrated approach. It will also enhance the understanding of requirements for safe implementation of the next-generation production control systems and their capability to improve vehicle safety.



Lotus rear steer actuator

The control objective is to combine full vertical, lateral/yaw and longitudinal control of vehicle motion, in a structured and systematic framework, to improve handling performance and stability. Lotus is currently undertaking a multi-phase Vehicle Dynamics research programme, to investigate the opportunities for improving a vehicles dynamic performance and safety using active control systems. The first phase, to build a vehicle with active rear steer, is complete whilst the second phase, to implement control of the ABS based yaw stability control system, is currently underway.

Through the use of high bandwidth hydraulic rear steer, the CVD (controlled vehicle dynamics) system will simultaneously control both lateral and longitudinal slip (and thus specify the direction of both tyre slip vector and the resulting force). This will provide yaw stability control of the vehicle, even in applications where neither road friction nor vertical tyre load information is directly available.

As expected, there are issues surrounding the safety of these complex steering systems, and this, is therefore, another key outcome from this work. The system management will therefore also provide real-time validation and integrity checking, fault-tolerant operation and diagnostic information gathering. The requirements for graceful degradation of safety critical electronic control systems will be explored, and design considerations will be integrated into future advanced vehicle programmes.

Looking to the future, with the combined use of active suspension, and suitable filtering techniques, it will be possible to simultaneously alter the tyre load distribution. This would enable maximum possible control of the available tyre forces. Integration of these into a layered multivariable control scheme goes well beyond the current capabilities of automotive manufacturers and systems suppliers. The dynamics envelope will be significantly expanded. Perhaps of more relevance to most of us, is that this enhancement will be in an area seldom experienced during normal driving, but during extremely uncomfortable emergency situations. It may be that the timely intervention of some control techniques could prevent an accident from happening.

Vehicle Refinement Technologies

Within the context of increasingly critical customer expectations and conflicting engineering targets, vehicle refinement is an area that can also benefit from continued research. This is particularly true with the potential introduction of various control strategies for engine and road noise in the near future. Again, Lotus is at the forefront of this research, having produced 30 EOC (engine order cancellation), 15 RNC (road noise cancellation) and 7 AEM (active engine mount) vehicles. Noise Synthesis systems have also been demonstrated and may prove of particular interest with the advent of electric vehicles.

Automotive customers are demanding increasingly high levels of refinement. However this is somewhat contradicted by the increased use of lightweight structures. Refinement is also often compromised by the need to satisfy strong market needs for optimised steering and handling. The desire to shed mass from our increasingly heavier vehicles can also restrict, or in fact, delete the adoption of traditional passive NVH materials. Furthermore, these passive NVH treatments are generally only effective at higher frequencies; therefore low frequency boom, one of the most tiresome noises, is more difficult to reduce.

Extensive platform sharing can lead to a dilution of individual brand characteristics and this is also true for refinement characteristics. There is a market requirement for greater differentiation, and noise control technologies can offer some solutions for NVH.

Why use Active Noise Control? Well it could be summed up simply as using the right tool for the right job. Active noise control is most effective at lower frequencies whilst palliative treatments are more effective at higher frequencies. However ANC is not a universal cure and will not provide a *"silent"* car.

Engine Order Cancellation (EOC)

A typical in-line four-cylinder engine exhibits high levels of second order (firing frequency) noise and vibration. This noise and vibration excites acoustic modes of the cabin. High levels of low frequency tonal noise (booms) are generated and the tonal nature of the noise is particularly intrusive and is linked to both driver fatigue and discomfort.

The technology is based on a simple concept – cancellation of undesirable noise or vibration through destructive interference. This is accomplished through the use of a real-time reference measurement of the undesirable noise or vibration and the subsequent generation of a 180º out-of-phase signal. The out-of-phase signal is used to drive an actuator (typically a loudspeaker).

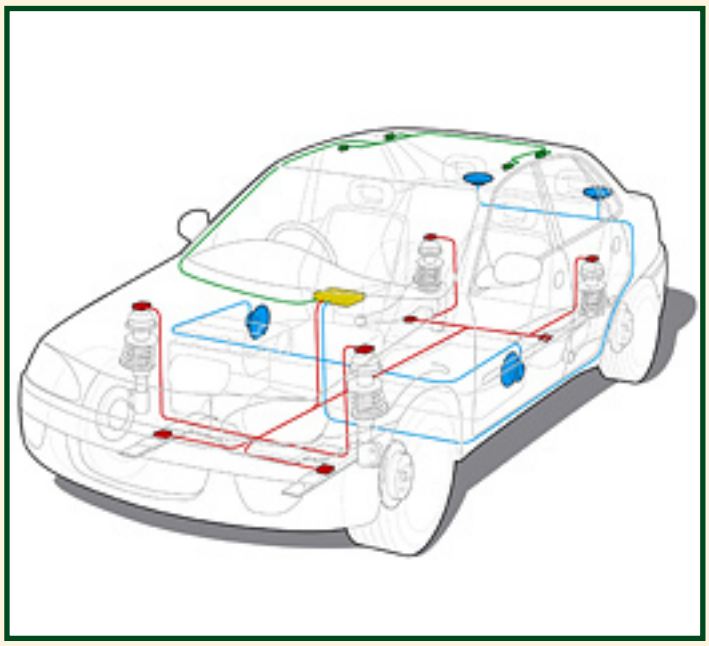
The system typically achieves reductions of 10dB or more in second order noise and has been found to be most effective between 50 -250 Hz. The lower frequency limit is constrained by loudspeaker bass response, whilst the high frequency limit is the cut-off for satisfactory global cancellation (that is, in all appropriate areas of the cabin).

"The Lotus RNC System employs a patented adaptive feed-forward control system to achieve broadband cancellation of low frequency road noise road noise"

Within the frequency limit, the system can cancel multiple engine orders, and it is also possible to cancel intake and exhaust noise. There are no restrictions on engine type (petrol/diesel) or configuration.

The EOC system is capable of driving different types of actuator. That is, it can cancel vibration or noise through the use of loudspeakers, Active Engine Mounts (AEMs) or Active Seismic Absorbers (ASAs).

The control system remains the same, and different types of actuator can even be combined within a multi-channel system. In this way, an AEM or ASA-based system is a viable alternative to engine balancer shafts. This can produce significant savings in power consumption (peak power consumption of 80W versus 1.8kW for balancer shafts). Optimising the use of EOC can lead to potential cost and mass savings of up to GBP20 and 15kg per vehicle. The system is integrated within the in-car entertainment system (ICE) so the cost of system implementation is minimal.



Schematic of RNC installation

Road Noise Cancellation (RNC)

Road noise is a significant issue in many modern vehicles. It is caused by excitation at the tyre and road interface and is characterised by low frequency broadband *"rumble"* or *"roar"*. The transmission path is primarily structure-borne. The Lotus RNC system was developed as a broadband solution to low frequency road noise.

The Lotus RNC System employs a patented adaptive feed-forward control system to achieve broadband cancellation of low frequency road noise. Accelerometers on the vehicle structure provide the controller with a feed-forward reference of the structure-borne element of road noise. The system takes

advantage of the propagation delay between the vibration input and the resulting noise in order to compute the necessary cancellation signal. The cancellation signal is output to the vehicle interior using the standard ICE system loudspeakers. Microphones in the vehicle interior ensure that the cancellation is continuously monitored and therefore optimised.

The system can typically achieve reductions of 8-12dB in low frequency road noise, subject to same frequency limitations as EOC, and is fully adaptive as the cancellation is continuously optimised.

Sound Synthesis

Sound quality is an important factor in communicating brand values as customers expect sound quality to match brand image. Recent changes to exterior noise legislation have further diluted the potential influence of engine noise on the perceived engine character. Sound synthesis can assist with this by enabling a wide range of qualitive noise improvements to be made within the cabin. It is possible to give a four-cylinder engine the aural quality of a V8.

EOC, RNC and Noise Synthesis were initially developed as separate technologies and at present each system requires its own bespoke controller. Lotus is currently integrating all three technologies into a single system known as ICAAT (In-Car Active Acoustic Tailoring).

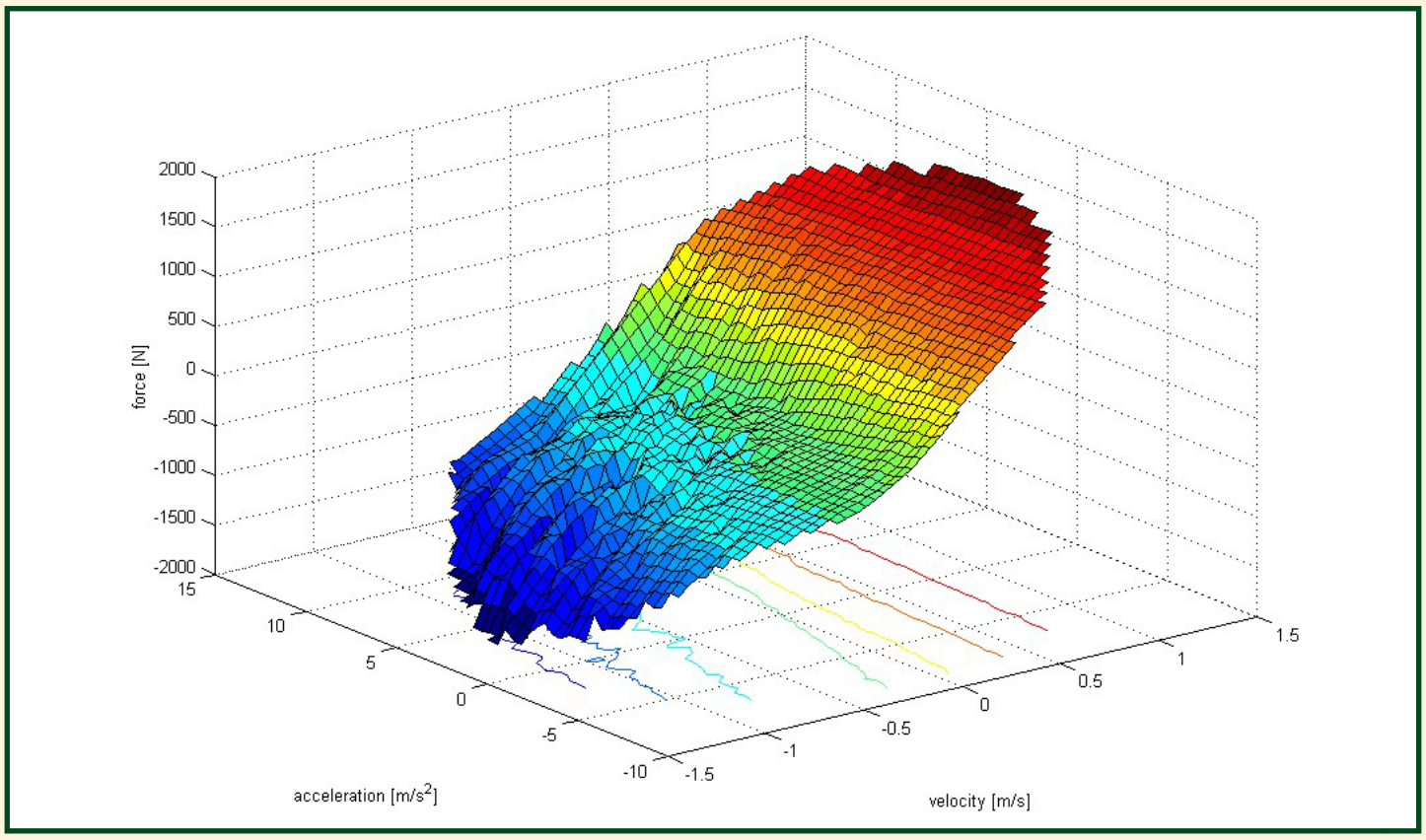
Damper Characterisation

Suspension dampers (shock absorbers) are a vital element in the chassis system and perhaps the single most influential component in the derivation of vehicle dynamic *"character"*. Lotus is unique in the automotive consulting world in understanding the mechanisms and benefits of optimising damper characteristics. If the damping has not been optimised, it will be impossible to create the correct chassis performance and hence vehicle attributes.

With customers becoming more critical and wheel and tyre sizes increasing, the chassis engineer is faced with a difficult task in deriving a suitable ride and handling compromise. Along with many other components, dampers and their mounts are critical to achieving the right blend of control and isolation.

Damper hysteresis has been identified as a potential measure of the efficiency of a given damper architecture at all velocities and accelerations. However, the complexity arising from the combination of both mount hysteresis and damper hysteresis can hinder the development of potential improvements for road vehicle ride performance. Suspension/damper hysteresis is detrimental to road noise, small bump absorption and steering feel.

It is well understood that damper performance is a function of acceleration. However, current methods for assessing damper performance do not fully take this into account; as a



A new approach for Damper Characterisation

consequence, damper performance is not fully assessed. In order to gain a better understanding of damper performance, it is necessary to develop both new test methodologies and new ways of presenting and analysing the measured data.

Recent research work conducted by Lotus Engineering in collaboration with Kingston University has looked at improving the test methodologies. This work has been concerned with two key areas: firstly, to develop the use of a road profile for the testing of vehicle dampers and associated mounts (to replace the current and simplistic sine wave test); and secondly, the generation of new methods of post processing and analysing the data.

We can expect several benefits by moving away from the standard sine wave profiles and adopting waveforms that are based on a mathematical model of a road profile. The new test profile will provide a better representation of the duty cycle that a damper experiences. It will also be possible to study some of the more complex relationships that exist within the damper. For example, the damper can experience a low frequency input, with a higher frequency content superimposed (representing vehicle body motions and road surface variations).

This behaviour can require significant oil flow reversals within the damper and can produce high levels of hysteresis as the internal valve structure seeks to control these flows. During chassis development, the wide variety of possible internal damper configurations directly influences the achievable vehicle characteristics. It is this issue that concerns the ride engineer, and he will carry out many changes to the damper configuration before arriving at a reasonable solution. It is possible, during this activity, that hysteresis could inadvertently be increased (although the force velocity relationship would remain unaltered). This would result in lower damper/vehicle performance and poor utilisation of the ride engineer's time. Therefore a new method that assists with optimising the damper is keenly sought.

Our initial work has produced methods that can quantify the level of surface roughness (*"noise"*) that can be seen on a 3D plot of force, velocity and acceleration. This *"noise"* is the hysteresis present in the damper or damper/top mount combination.This type of plot gives a visual indication as to where in the operational spectrum the hysteresis is dominant. There are numerous standard absolute and statistical values that can be extracted from these curves to fully define the damper's performance. However, it was considered that these did not fully illustrate many of the differences that were thought to be present (from a damper perspective). Therefore a number of other analytical approaches were developed with Kingston, and Lotus now has a revised processing technique which can quantify the magnitude of the hysteresis as a function of acceleration and indicate where the hysteresis occurs within the damper cycle. This new approach has been shown to give much more detail than current methods and explores areas simply not possible with current techniques. It therefore allows for much more precise tuning of the damper and/or top mount, identifying which part of the valve structure, or mount, needs attention. Tuning the damper and elastomer together enables top mounts to be matched to damper performance or vice versa, resulting in noticeable improvements in ride quality without compromising damper performance.

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