



pro **Active**

The official industry newsletter of Lotus Engineering

Issue 12

January/February 2006

*Does CUV spell
Detroit's salvation?*



*Alternative
powertrains*



Welcome

Welcome to issue 12 of *proActive*. The pace of change in the modern world is frenetic. The car is an integral part of that world and as such it has to keep pace with customers' needs and wants for change as well as satisfying legislative demands for increased levels of safety and improved emissions.

These factors, amongst many others, influence the shape and direction of the activities Research & Development (R&D) organisations of the worlds' automotive companies undertake. This will also influence the look of new vehicles hitting the marketplace and the technologies inside them.

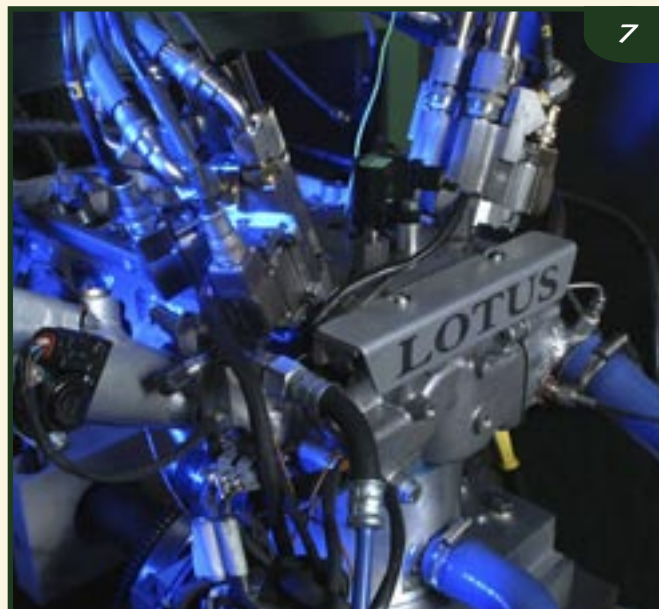
In this issue of *proActive* you will read about concepts as diverse as medium volume production vehicles built from aluminium, powered by engines using cutting edge combustion processes, reduced complexity, component count and weight. And whilst driving these vehicles even the seat holding you will be looking after your body posture and blood flow. If you are sitting in the latest Elise or Exige, which are the first vehicles in the world to feature ProBax™, you are already experiencing the benefits of modern R&D.

Clive Card

Project Manager, Research and Technologies



Clive Card



Contents

January/February 2006

news

CHINA: Now world's second largest vehicle market but profits declining 3

US: Successful suppliers align strategies with product value 3

RUSSIA: AvtoVAZ develops strategy for 2020 4

features

Does CUV spell Detroit's salvation 5

R&D: Meeting the challenges of the 21st Century 7

Concepts to reduce architectural complexity and mass in reciprocating engines 10

Alternative powertrains 14

2006MY Lotus Elise and Exige - Auto Industry First Application of ProBax™ Seating Technology 16

Toyota sets out a global vision 18



CHINA: Now world's second largest vehicle market but profits declining

China is now the second largest vehicle market in the world, with total sales of 5.92m vehicles in 2005, up 15% on 2004, according to the Shanghai Daily newspaper. China overtook Japan, which sold 5.82m vehicles and now only lags behind the US.

The Chinese sales figure for 2006 includes 160,000 imports.

Total vehicle production reached 5.7m units, up 12.5% on a year earlier. 2.95m of these were cars, up 26.9% on a year earlier, according to the newspaper.

For 2006 Reuters reported that the China Association of Automobile Manufacturers (CAAM) is forecasting sales and production to grow 12%, slightly lower than in 2005.

High raw material prices and a price war in 2005 contributed to a decline in profit margins at Chinese vehicle manufacturers

However an executive of the Union of National Passenger Car Market Information, quoted in the Shanghai Daily, is slightly more optimistic and expects growth in 2006 to match 2005's growth of 15%. This means sales would reach 6.4m units.

A Deutsche Bank analyst quoted in the Shanghai Daily expects sales in 2006 to be fueled by a drop in the price of raw materials and strong demand from the growing middle classes.

High raw material prices and a price war in 2005 contributed to a decline in profit margins at Chinese vehicle manufacturers. According to the National Bureau of Statistics, the average profit margin in 2005 was 4%, well below the 6.86% recorded in 2004 and 9.11% in 2003. Profit margins are unlikely to reach 2003 levels again.

Source: just-auto.com editorial team

US: Successful suppliers align strategies with product value

Suppliers that closely align their competitive strategies and business models with the value their products offer are leading their peers in revenues and profitability, according to a new study from Accenture.

High performers in the supplier industry generally fall into one of three groups:

- Low-cost producers — These high performers optimise their material and production costs on a global basis. They take advantage of low cost sources of goods and services in places such as China, India and Eastern Europe, and they locate production facilities to optimise scale and total cost. For them, a relentless pursuit of lean overhead is critical to success.
- Differentiated producers — Successful suppliers in this segment (suppliers of electronics, safety systems, etc), push the innovation envelope. They excel in pioneering R&D and engineering, fully integrate product development with OEMs and have highly technical niche product capabilities that demonstrate pricing power with the OEM and the consumer.
- Hybrid producers — Some suppliers achieve high performance with both commoditised and highly engineered portfolios – but do so by establishing operating companies dedicated to either the commoditised or highly engineered segment. They manage these through a holding company.

The study looked at 31 of the top Tier 1 suppliers, all quoted companies.

The top five companies in the study maintained superior revenue growth (12% average annual growth over the past five years) and superior profitability (5.4% compared to 4.0% average EBIT margins over the past five years).

Other common success factors amongst high performance companies include the fact that they invest more than their peers in R&D, and that, while they did not conduct any more or less M&A activity than the average, they executed post-merger integration more successfully.

Source: just-auto.com editorial team

RUSSIA: AvtoVAZ develops strategy for 2020

AvtoVAZ, manufacturer of Lada cars, says it will build a new plant to produce 450,000 cars a year and develop a new platform for a series of cars, reported the Russian news company SKRIN.

The leading Russian carmaker faces an uncertain future as it loses its share in the Russian car market (which is currently booming on the back of an economic fillip provided by high energy prices). The share of the car market taken by foreign makes — many with vehicle assembly operations in Russia — is increasing while indigenous makers such as AvtoVAZ lose its share.

As Russian consumers eschew cheaper local brands in favour of the more expensive but more reliable products from international brands, the strategic questions facing AvtoVAZ have been thrown into sharp relief. The company faces dwindling volume at home allied to low exports; in global markets it is hampered by products seen as outdated (for example, fitted with engines that do not meet EU emissions rules) and subject to quality shortfalls.

Speculation has grown about whether the company will find an international partner prepared to invest in AvtoVAZ, seek more Russian government support or develop a survival strategy based on its own resources. It could be a combination of these elements, AvtoVAZ-watchers say.

***The share of
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AvtoVAZ department of development

The AvtoVAZ board met on February 2 and decided on a new strategy extending out to 2020. The strategy ostensibly suggests a go-it-alone approach, although industry observers point out that AvtoVAZ has issued similar grand strategy statements in the past and little has come to fruition.

Under the latest strategy, a new 450,000-unit annual capacity plant will be ready within three years. It is planned that eventually AvtoVAZ will have three platforms to produce 12 car models, including a small sport coupe, a crossover, a minivan, a new off-roader, as well as new sedan models for B, C and D segments. The plant's freshly installed management says that the new strategy relies heavily on local expertise with some foreign co-operation on parts and equipment.

AvtoVAZ executives have recently claimed that improved security measures have already saved 'many millions of rubles'. The giant AvtoVAZ Togliatti plant produces around 700,000 vehicles a year but has been a scene of extensive criminal activity in the past (every third vehicle leaving the assembly line was once said to be unaccounted for). The company also has a joint venture with GM making the Niva SUV (Chevrolet Niva in export markets), but GM has steered clear of significantly raising its investment or developing closer ties with AvtoVAZ.

In early February, the office of Russian President Vladimir Putin floated a proposal that AvtoVAZ could form the cornerstone of a new state automotive conglomerate. Drawn up by Federal Industry Agency head Boris Alyoshin, who sits on the board of AvtoVAZ, the proposal calls for the formation of a single corporation comprising car, truck and bus production.

The Russian state took effective control of the board of AvtoVAZ late last year.

Source: just-auto.com editorial team

Does CUV spell Detroit's salvation?

In North America, there is much talk of a shift in light vehicle market segmentation precipitated by higher gas prices and changing consumers' tastes. Some analysts say that demand for relatively large and heavy light trucks will see a decline in favour of smaller and more fuel-efficient vehicles. Crossover Utility Vehicles (CUVs) could be a significant part of that trend and plenty of new product is coming. David Robertson reports.

The problems besetting the North American auto industry are hard to avoid and there is concern that it is only a matter of time before one of the big manufacturers hits an iceberg.

However, it is not all bad news and the growth in popularity of the crossover utility vehicle (CUV) offers hope, and possibly a life vest, for some troubled companies.

At the recent Los Angeles and Detroit auto shows, motor industry executives spent most of their time, when not buried in the appointments section of newspapers, praying that their new models would perform better than 2005's.

Vehicle sales in North America rose just 0.8% to 16.9m last year despite the industry spending a staggering \$42bn in incentives, according to Edmunds.com. General Motors and Ford were the hardest hit with sales down 4.2% and 5% respectively.

The GM and Ford drop has been attributed to a spike in gas prices, which pushed a gallon over \$3 for the first time. Fuel economy has now become a consumer priority and, as a result, the sports utility vehicles (SUVs) and trucks that have supported the big two in recent years have declined in popularity.

SUV sales were at their lowest level since 1998 and the biggest SUVs like the Lincoln Navigator and Cadillac Escalade saw 10% to 20% drops on the previous year.



Jeep Compass

Of course, the SUV market isn't dead, but manufacturers have been forced to alter their sales pitch. The new model Chevy Tahoe, for example, is being promoted for its fuel economy – a claim that could only be made by a company that is getting good at denying the obvious.

The dip in SUV popularity corresponded with the first rise in car demand since 1992. The car share of the North American auto market rose to 45.1% compared with 44.3% the year before.

The other big winner in 2005 was the CUV, and even greater things are predicted for this market segment in 2006.



Ford Escape

Ford's new president of the Americas, Mark Fields, told journalists in Los Angeles: *"Today's fastest-growing vehicle segment in the United States is crossover utility vehicles, or CUVs. CUV growth is now outpacing the remarkable growth SUVs achieved in the 1990s... and they are on pace to exceed traditional SUV sales for the first time ever."*

In 2000, about half a million CUVs were sold in North America compared with 2.97m SUVs. In 2005, according to Ford, 2.24m CUVs were sold versus 2.4m SUVs.

2006 will almost certainly be the changeover year when CUVs overtake SUVs.

There are already 41 crossover models on the market (compared with just 14 in 2000) and Ford expects that number to reach 50 by the end of the year – the same number of models that SUVs managed in 2000 when SUV sales peaked.

Merrill Lynch has dubbed the CUV *"the new SUV"* and Ford is calling these vehicles the *"next major evolution in what we drive"*.

Feature

Ford has good reason to shout about the growth of CUVs as it has the best-selling model: the Ford Escape – aptly named, as this vehicle may help Ford to dodge the problems it has recently faced. Ford saw CUV sales grow by an impressive 42.3% in 2005 and the Escape sold over 160,000 units.

New CUV models featured prominently at the Detroit auto show, including the Acura RDX, Buick Enclave, Ford Edge, Lincoln MKX, Hyundai's second generation Santa Fe and Kia's Soul (which must be a poorly spelled attempt at national pride).

Even Jeep has produced the Compass, the division's first car-based vehicle and the first that isn't designed for off-road – although it is hard to imagine that the average SUV or Jeep driver will notice the difference.

Crossovers were born in the mid-1990s when foreign automakers rushed to grab a slice of the SUV market. Detroit manufacturers were able to use existing truck and pickup architecture to build these new family vehicles but foreign auto companies had no truck models and were caught out when SUVs took off.

Instead, foreign manufacturers used car platforms and loaded them with super-sized bodies. Fortunately the designs have improved since the early days and CUVs are less likely to roll over going around a corner than they used to be.

However, to European eyes, the new generation of CUVs still look as though they've been given an injection of steroids (they are about the same dimensions as a 1990s minivan) but in North America CUVs are a happy compromise between the need for size and the need for fuel efficiency.

As Mark Fields of Ford explained: *"Two distinct market trends have helped fuel this explosive growth. Car buyers are seeking more spacious and flexible interiors, along with the security of all-wheel drive. And many traditional SUV buyers are seeking more manoeuvrable and fuel efficient vehicles that still make it possible to have an active lifestyle."*

Jeff Beddow, spokesman for the National Automobile Dealers' Association, said: *"Sales have been very strong in this sector and it has been the fastest growing part of the auto industry. Our economists are predicting that crossovers will continue to be a big growth area. Part of the reason for this is fuel efficiency and also because people like the way they drive and park. They like being higher up but don't want a vehicle that is quite as big as the SUVs are now getting."*

The current top five CUVs are the Escape, the Honda CR-V, Toyota Highlander, Honda Pilot and Chevrolet Equinox (at this rate GM and Ford will soon run out of Es to name their vehicles: Escalade, Escape, Edge, Enclave, Equinox...)

The big news for the Detroit manufacturers is that they have two models on this top-five list, which, considering CUVs were developed by foreign automakers, represents significant progress. Detroit now has 47.6% of the CUV market, up from 42% in 2004

and the American companies are reporting growth rates that are much higher than their rivals.

One of the reasons for this is that American manufacturers are producing crossover models that are larger than the imported brands – and this continues to appeal to many consumers.

Michael Albano, director of communications for Chevrolet, said: *"From a size point of view we've hit the sweet spot with our Equinox and HHR models. They are a little bit bigger than some of our competitors and that, along with our styling and the flexibility of our interiors, is attracting customers."*

The problem with CUVs is that their sticker prices are much lower than those for SUVs and, as a result, profitability is also lower. SUVs are thought to generate a fantastic \$10,000 to \$15,000 profit per vehicle while CUVs have an estimated profit margin of \$6,500 to \$8,000.



Chevrolet Equinox

General Motors insists growing crossover sales are not coming at the expense of SUVs and the profitability issue is, therefore, irrelevant.

Michael Albano said: *"Our crossover models are plugging holes in our range. They are adding volume and we don't see a direct correlation between crossover growth and SUV decline."*

This might be wishful thinking but, for desperate automakers in need of a good start to 2006, any sort of sales growth is welcome. Let us just hope that the success of these crossover models is not the jaunty tune being played by a Detroit band while the ship goes down.

Source: David Robertson, just-auto.com editorial team

R&D: Meeting the challenges of the 21st Century

"No man is an island, entire of itself, every man is a piece of the continent, a part of the main..." John Donne (1573-1631).

The work of producing vehicles to meet the demands of the new century has to encompass every aspect of the art and science of automotive engineering. Engineers and designers from every discipline need to interact more closely with each other and with a deeper understanding of the effects of their decisions on the vehicle as a whole. No one aspect of the vehicle should be dominant if it is to achieve optimum performance whichever market segments it's intended for. The end product should be a coherent assembly of technologies, optimised to deliver appropriate performance.

What will the 21st century vehicle look like?

Crash and impact legislation will have a significant effect on the exterior and interior profiles of the vehicle. From the type and quantity of fuel used, through to the combustion strategies employed, reduced and very low CO₂ emission levels are the medium term goal. The eventual target is for zero greenhouse gas emission vehicles, hydrogen fuel cells. Noise emissions remain a target for legislation, as does crash worthiness and minimising the danger vehicles pose to pedestrians and other road users. Not to be forgotten is the environmental impact of a vehicle's eventual disposal and recycling at the end of its useful life. All these aspects need to be considered, accounted for and addressed at the outset of a new vehicle project.

How do we get there?

Back in the early 90's it was relatively standard custom and practice for engineering organisations to operate sequential engineering. Here a completed piece of work was effectively "chucked over the wall" to the next department or function in the chain. The net effect was lengthy engineering programmes and longer time to market. Academics and industry were all too well aware of the time being unnecessarily consumed and started to carry out activities simultaneously rather than consecutively. For example, was it really necessary to leave manufacturing analysis of a component until the design was completed and released? Why not conduct this activity alongside the design process? The new working practice got a new name; Simultaneous Engineering. This hand-in-glove approach marginally lengthened in process sub-tasks but drastically reduced overall project duration. It also fostered even closer ties between different engineering disciplines such as design and manufacturing engineering.

So how does this concept sit with the R&D challenges for the automotive industry of the 21st century? For a start, as engineers and manufacturers, we have to ensure that developments in automotive technology used in our products are complementary so relevant performance criteria of that vehicle can be maximised whatever its segment. All its systems need to work in unison to do so. Vehicles with hugely powerful engines and, what can best be described as idiosyncratic ride and handling characteristics, are a thing of the past. That does not mean, however, that vehicles need lack character in any aspect of their performance or looks.

Where does it all start?

The only part of a wheeled vehicle we want to be in contact with a hard surface is the tyres. They are fundamental to the ride and handling of the vehicle. In the case of a racing vehicle, they are also fundamental to lap times. Engineers spend their working lives trying to extract maximum performance from them. Road vehicle tyres demand a different blend of performance characteristics. Firstly, unlike race car tyres, they have to perform in a wide range of weather conditions. Rather than producing optimum lap times they have to provide optimum safety, longevity and fuel consumption.

Suspension systems and the Lotus' Suspension Kinematics & Compliance Measurement System (SKCMS)

In order to optimise the capabilities of the vehicle's tyres, its suspension and steering systems need to be designed and developed to provide the required ride and handling characteristics. At Lotus, one of the tools we use is our in-house designed and produced SKCMS. This measures the suspension and steering characteristics in relation to the displacements and forces acting on the road wheels. The degree of accuracy of the data collected on the SKCMS allows Lotus engineers to construct full system models in bespoke software, namely Shark & Raven, where geometric and compliance specifications can be changed and the results viewed. The iterative process continues with modifications to the vehicle itself which can then be re-tested on the SKCMS to prove out and also by the Ride and Handling development engineers on test tracks and roads.



Lotus SKCMS

Feature

The world is realising

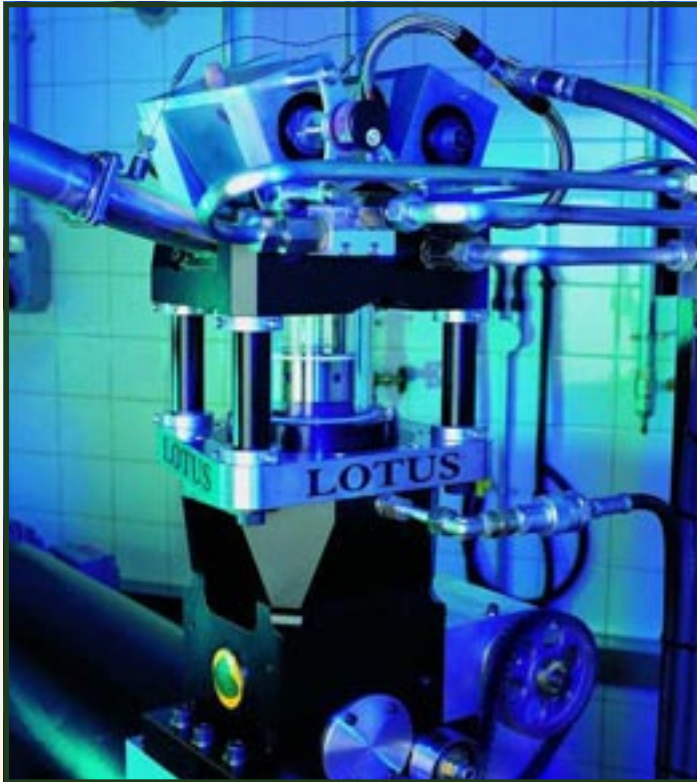
The effects of our modern lifestyle on global warming are becoming matters of increasing concern the world over. In reaction to these concerns and initiatives such as the Kyoto protocol, European OEMs have signed up to achieving fleet average CO₂ emissions of 140g/km by 2008, with stretch targets of 120g/km by 2012. Even America is realising the need to reduce emissions and the President recently articulated two important concerns.

"America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology." George W. Bush, State of the Union speech 2006.

Modern powertrain technology is focused on achieving the maximum power output from a given amount of fuel burned or, to look at it another way, how little fuel can we burn to achieve a certain power output?

Downsizing

At Lotus we are currently running research engines to investigate engine downsizing, primarily with a view to replacing large capacity, normally aspirated engines with smaller capacity units using innovative pressure charging systems. The results of these activities are starting to be disseminated through symposia and scientific journals to the automotive engineering community.



Optical access engine

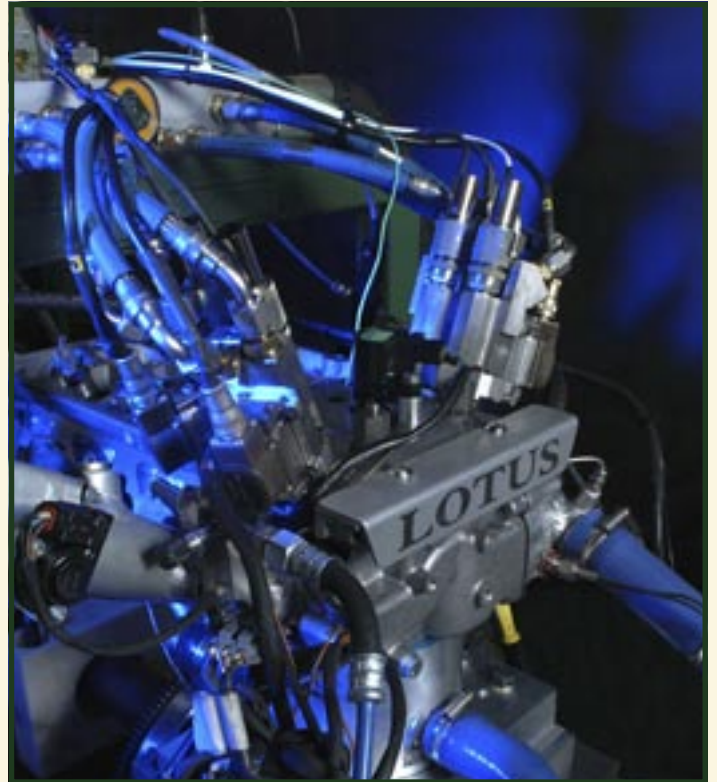
We are currently running research to investigate engine downsizing

GDI research

In collaboration with Siemens VDO, Loughborough University and University College London, Lotus is now starting year two of the HOTFIRE project (Homogeneous and Throttle-less for Fuel Efficiency with Reduced Emissions). The consortium objective is to develop an homogeneous charge direct injection strategy offering increased fuel efficiency and a lower system cost. Lotus has now supplied and commissioned two single cylinder research engines to support this project; an optical engine for laser diagnostic work at Loughborough and a firing engine for combustion analysis at UCL. Fundamental to the success of the project is the use of Lotus' Active Valve Train™ (AVT™) as an enabling technology.

Blurring the edges, chassis technology inside engines

AVT™ is a direct descendant of the Active suspension systems first glimpsed on Lotus' Formula 1 Grand Prix cars. As such, it illustrates how innovative technologies can have a wide range of uses and applications which can be very different from the original intention.



AVT blue light research engine

Feature

Where are we going ?

The fuels we burn are the second aspect alluded to by George W Bush. In the UK, British Sugar has just broken ground at Wigginton in East Anglia where the country's first bio-ethanol producing plant will be built. If you couple the green credentials of bio-ethanol and other bio-fuels with security of supply, the attractiveness of the technology to the automotive world and associated interested groups, is clear. Both Saab and Volvo have vehicles currently in production that are capable of running E75 bio-fuel.

Vehicle fleet average CO₂ emission reduction is the way forward. In order to achieve this manufacturers are likely to continue offering diesel engines. More hybrids will be manufactured. Firstly, we are likely to see an increase in market share for gasoline hybrids and then a shift to diesel powered versions. Alternative gaseous fuels could become more popular in countries where the market wants to keep driving large capacity spark ignition (SI) engines. In all likelihood there will be a move to more pressure charged designs. Hydrogen fuel cell vehicles are the future the industry is working for, however, this is still some way from reaching production reality.

Aluminium and composite technologies

Lotus Engineering has always been associated with innovative automotive technologies. Elise showcased the first application of bonded aluminium structures in road vehicles. Light weight, immensely strong and rigid and by using extrusions able to be produced in complex bespoke forms at low cost, the Elise established a new benchmark in how to produce exciting low to medium volume vehicles cost effectively.

Another first for Elise was the use of a thermoset composite crash structure. The component was designed to be sacrificial, in the event of front-end damage it can be simply replaced, the crash loads having been largely isolated from the main aluminium structure of the vehicle. Our engineering customers liked this concept and could see the relevance of the technology for their own vehicles. As a consequence Lotus was commissioned to apply the technology to the Aston Martin Vanquish by designing, engineering and developing a thermoset composite front crash structure for it. Subsequently, Lotus was asked to manufacture the structure and it is now produced at the company's Hethel headquarters.

Thermosetting composites are light and strong and clearly offer excellent energy absorption properties and, for low volume manufacturing, the cycle time satisfies the critical path production. Unfortunately for medium volumes cycle times are just too slow. In order to address this issue Lotus and Jacob Composites set out to engineer, develop and manufacture the ECOLITE front-end crash structure using thermosetting composites.

Thermoplastics offer a number of useful benefits to the automotive industry. Obviously, the materials have to provide sufficient energy absorption properties to be used in the construction of composite vehicle crash structures. As important for manufacturing is cycle times, and these are significantly shorter than thermosets. Typical in tool cycle times are three to four minutes for compression moulding compared to hours in the case of thermosets. Part of the attraction of thermosets is the potential economical viability for medium volume vehicle production (30,000-50,000 units per annum). Not only would this give the opportunity to produce a number of BIW variations quickly and cost effectively, it would also offer the chance to satisfy consumer demand for updated vehicles as product life cycles continue to shorten.

Aluminium structures for vehicles are also evolving. In October 2004, Lotus unveiled the philosophy of the Versatile Vehicle Architecture (VVA). The concept is to use aluminium castings at specific positions in the Body-In-White (BIW) which form the basic building blocks. Aluminium extrusions are added to these castings along with pressed aluminium panels to complete the structural elements. The BIW would be joined by a combination of bonding and riveting processes. These processes avoid introducing stresses in the vehicle structure, which is an undesirable feature of welded assemblies.

By March of 2005, Lotus had completed a representative BIW structure and this was displayed at the Geneva motor show.

Conclusion

This year's Geneva motor show will see the public unveiling of the APX vehicle. This fully running prototype embodies many of the technological philosophies Lotus has been following in its R&D programmes. The vehicle body is the conclusion of the initial phase of VVA and its powertrain is a new Lotus pressure charged unit, ready for the production development phase after only 18 months. Linking complementary R&D activity has been fundamental to delivery of the vehicle on display in Geneva. We trust you will appreciate the end result.

Clive Card



APX by Lotus Engineering

Concepts to reduce architectural complexity and mass in reciprocating engines

The architecture of 'modern' engines is ninety years old, following the laying down of the Napier Lion aero engine in 1916. Four-stroke engines and the architecture of poppet valve control for intake and exhaust, separate cylinder head and block, and non-drive-side timing drive architecture can be traced back through many generations directly to the Napier engine. It was the Napier engine which exhibited that modern characteristic (wrongly attributed to the Cosworth DFV) of a single cam cover for its double-overhead-cam 4-valve-per-cylinder valve train.

Consequently, the modern automotive 4-stroke engine is a robust, highly developed system which is made from relatively cheap materials and is cost-effective to produce. As an assembly, however, it is having to become more complex with new, expensive sub-systems being added, most notably, gasoline direct injection (GDI) and hybrid drive components.

In the years since the Lion, various concepts to simplify or improve the basic formula have been tried and discarded to leave the automotive engine as we know it today. Some of these concepts were abandoned due to manufacturing issues and some have not found common usage due to a perception that they are unlikely to be durable. To these must be added a third group, which are only just becoming feasible due to advances in other areas (such as the use of industrial adhesives instead of mechanical fasteners). How some of these concepts can be used to reduce the mass, cost and complexity of the base engine architecture, and so to allow the adoption of new technologies within vehicle cost constraints, are discussed below.

*There has been a
move back to single-
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construction*

The monoblock

'Monoblock construction' commonly refers to the incorporation of the cylinder head and block into a single component. This is in contrast to the modern approach of providing a split between the cylinder and block which then requires a high-pressure gasket. However, engines were not always manufactured in this split-construction manner. Early high performance engines, such as the Bugatti Type 35 and Delage 15-S-8, were of monoblock construction [7], primarily because these were racing engines burning high quality fuels. As a result, they did not suffer from the coking common in engines fitted to mass-produced cars burning less exotic fuels. In this mass-market, owners frequently had to 'decoke' their engines, an operation made much more simple by the use of a removable cylinder head and by a side- or overhead-valve architecture.

Later, as better fuels became available, manufacturers began taking advantage of a cylinder head split line and making the cylinder block and heads from different materials. Commonly aluminium alloy became adopted for the head (because of its superior heat rejection properties) and cast iron was adopted for the block (for cost reasons coupled with the fact that it also provided a good rubbing surface for the piston rings). Since then, there has been a move back to single-material construction so that the norm is to employ what is referred to as 'all-alloy' construction. Since the days of decoking are long gone, there would seem to be no impediment to returning to a monoblock architecture.

In the current engineering climate, doing this would offer several advantages:

- The cylinder head gasket is eliminated, to the benefit of reduced bill-of-material (BOM)
- An entire set of critical fasteners can be removed from the engine mass and BOM, thus further reducing cost and increasing structural integrity
- Removal of the head bolts and their tubes also gives more freedom in the design of the upper part of the engine
- Distortion in the upper area of the engine due to the high loads typical of cylinder head bolts can be avoided
- Removal of the horizontal surfaces of the split line allows fewer compromises in cooling jacket design and more freedom in positioning under-port GDI injectors

Modern engines have been built using this architecture. An example of a monoblock designed and used by Lotus in a research engine built for the Formula 1 1.5 litre engine formula of the early 1980s, is shown below. This used direct injection from under the intake ports and, from the figure, it can readily be discerned how the elimination of the head gasket allows greater freedom in its position and orientation. Also clear is the simplification in the design of the top of the engine due to the removal of cylinder head bolts and their tubes.

Feature



Research racing engine monoblock. Note direct injector position under the intake ports; these are in a position which would usually be occupied by a cylinder head gasket

Despite the advantages there is one serious challenge. Although machining and honing the cylinder bores did not present any major difficulties in the L9 project, the conventional way of configuring a modern engine, with one of its major horizontal split lines above the bore, allows free access to the cylinder head valve seats and guides from the combustion chamber side so that these surfaces can be machined in one operation to ensure their concentricity.

However, it is a trend in modern four-valve-per-cylinder gasoline engines to adopt steeper valve angles and this will help in the consideration of whether to employ a monoblock or not. Furthermore, larger bore diameters will assist too as this has the effect of shortening the cylinder liner. A separate liner arrangement which is only inserted after the valve guides and seats have been machined, would also assist in permitting the monoblock approach, and this has been successfully achieved by Lotus in a 2-stroke design (the ELEVATE experimental engine). Historically, this separate liner approach has been successfully implemented by Alfa Romeo and so is not without successful precedent.

The above consideration of valve angles does not, of course, apply in the same way to diesel engines, whose valves are commonly vertical and furthermore not as large as is common in gasoline engines, which have to have better high speed breathing. The diesel is also extremely highly loaded in terms of cylinder pressure (maxima of 180bar are common in high-speed direct-injection automotive types), and so their cylinder head gaskets would benefit all the more from being eliminated.

In a conventional combined crank case cylinder block, coolant must be carried by that part of the assembly which holds the main bearings for the crankshaft. Recently, there has been a resurgence of interest in magnesium as a material for the scantlings of internal combustion engines, with BMW introducing a complex compound casting in which aluminium is used as a coolant jacket and bore surface, with a structural magnesium shell

cast around it. This is because magnesium is attacked by water and so is not normally an ideal material for crankcases. With monoblock construction, however, since the crankcase no longer has to contain coolant, the material is simple to incorporate and is used in an environment ideal for it, where it can be employed to the benefit of mass reduction.

In summary, the monoblock offers significant advantages in terms of parts reduction and assembly, mass, positioning of modern injection systems and ease with which magnesium can be adopted for other parts of the structure. Against this, the disadvantages are twofold: the intake port needs to be redeveloped to accommodate the steepened valve angles (in the case of gasoline engines) and the assembly process is slightly different. In the authors' opinions, the potential advantages outweigh the disadvantages which is why a concept engine was designed by Lotus to showcase the monoblock in a cost-effective road engine; this is shown below.



Lotus 'Jewel' concept engine: monoblock construction, magnesium ladder frame and composite water jacket, oil drains and cam cover

In this illustration are discernible the separate magnesium ladder frame bolted to the underside of the monoblock, together with the simple plastic wall of the cooling jacket, within which is a plastic oil drain. This approach makes a good noise insulator. At the top the cam cover is within a further noise containment jacket, and is made from composite. It was intended that these covers be slid onto the main assembly and bonded in place, a subject returned to below but, even without this, it can be seen that the monoblock could be developed into an excellent architecture to reduce mass and improve assembly issues.

Feature

The integrated exhaust manifold

Conventionally, managing the release of exhaust gases from internal combustion engines has been handled by a separate exhaust manifold. This is particularly true of automotive applications where runner system flow and system tuning are typically application optimised for peak engine performance and torque characteristics. Production applications, where legislation heavily influences engine sub-system design, are now required to include close-coupled catalyst systems as a solution to regulative emissions requirements. As a result, manifold tuning potential diminishes, not only because of the resultant short exhaust runner system, but also because of the attenuating effect of the close proximity of the back of the exhaust valve to the catalyst substrate. Additionally, cast iron manifold designs are often compromised, from a performance perspective, to enable demanding modern durability targets to be met. The alternative is to switch to lighter, high-specification, tubular, stainless steel materials which also bring with them high costs. Consequently, the separate manifold now offers diminished functionality and desirability in the economy market.

It is possible, however, to integrate the exhaust manifold with the cylinder head casting and so reduce the BOM. Water cooling of exhaust manifolds has been successfully performed for many years in the marine sector, with the supercharged Mercury Marine Verado engine routing its exhaust gases through a water-cooled exhaust manifold integrated into its aluminium cylinder head, and then through its block casting.

As a result of integration of the exhaust manifold into an aluminium cylinder head casting, substantial mass, cost and emissions benefits have been realised in a research project conducted by Lotus Engineering. The emissions benefits might be unexpected, but are the result of accelerated catalyst light-off through lower volume before the catalyst and more rapid heating of the coolant. In addition, many other less important but still significant benefits have been noted; these include improved underhood thermal management, subjective noise quality improvement, faster cabin heater warm-up and important benefits too in catalyst durability as a result of significant high load exhaust gas temperature reductions.

Consequently, thermal stresses across the cylinder head were reduced, and distortion was actually reduced

As all of the manifold features were now to be integrated, many packaging opportunities arise which would not otherwise have been available in a conventional high volume application, e.g. line of sight nut runner clearance, receiving bolt bosses in the head, planar gasket face all no longer needing to be provided etc. Thermal analysis also indicated a substantial reduction in the thermal gradient across the cylinder head as a result of the exhaust system side of the head now benefiting from water cooling. Consequently, thermal stresses across the cylinder head were reduced significantly, and distortion was actually reduced.

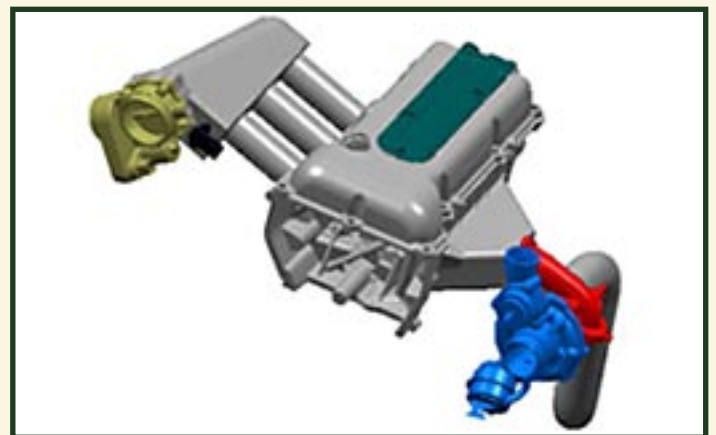
These results have been found on naturally aspirated and also turbocharged versions, where high load fuel enrichment has been reduced as a result of the engine cooling system removing some of the thermal energy from the exhaust gas and so reducing turbine inlet temperature. In turbocharged engines both catalyst light-off is improved and turbolag reduced due to a reduction in exhaust manifold volume.

As a result of these findings, the key desirable features of an integrated exhaust are, therefore:

- Reduced assembly mass (including the extra coolant)
- Compact size (to reduce handling and dunnage requirements and to improve package flexibility and vehicle crashworthiness)
- Flow optimised exhaust gas runners, since the tuning requirement is negligible in combination with close-coupled catalyst

The challenges can be said to be:

- Minimising the cooling system volume increase to minimise the impact on water pump demand
- Arranging the use of a single core runner system to improve manufacturing issues
- Arranging a single core water jacket architecture



Lotus downsized GDI research engine cylinder head assembly showing integrated exhaust manifold and turbocharger

Feature

Through careful application of sound design principles and analytical validation techniques, early testing of prototype hardware has demonstrated extremely positive results with cylinder heads completing structural and thermal durability tests in the first phase. As a consequence of these findings Lotus Engineering's next multi-cylinder GDI research engine has been configured with an integrated exhaust manifold before its turbocharger; an illustration of the cylinder head assembly of this engine is shown below. In concert with GDI, cam profile switching and wide range camshaft phasing on the intake and exhaust, the integrated exhaust manifold is expected to improve fuel consumption and emissions markedly beyond the current norm.

The use of industrial adhesive to eliminate non-critical fasteners

At present, US On Board Diagnostics requirements call for 150,000 mile durability of the engine between air filter and catalyst outlet. It is not permissible to disturb any part of the engine within this mileage with the exception of oil changes and spark plugs. At the same time, the present convention is to attach many of the ancillary components to it by screwed fixings.

Since disassembly is effectively not permitted, this means that the engines carry a serious cost disadvantage throughout their life (both as individual powerplants and throughout the life of the engine design).

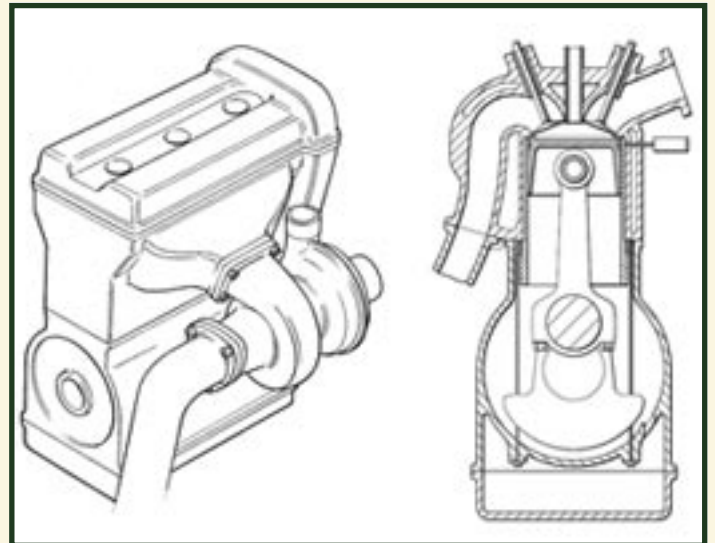
Against this backdrop it could be suggested that engines appear to be engineered for the development phase, because several of its covers, including the sump, front cover, rear seal carrier and cam covers could all be bonded to the structure instead of screwed. As well as reducing BOM cost, there are advantages in improved structure stiffness and reduced design complexity for tool access. However, at present there are not structural adhesives capable of surviving temperatures much in excess of 130°C, and so thought would have to be expended on where best to apply these adhesives. Loctite 5910 is often used to effect the seal between panels, and screw fixings provided as well; in reality joints using this technology need to be peeled apart after the fixings are removed, and so some investigation of the use of adhesive only would seem to be merited. Just one example of a potentially beneficial area to do this would be in complex castings which require cover plates for core access holes.

Conclusions

Despite being a well developed and refined system, there is still some scope for innovation in modern poppet-valve engines in the field of its overall construction. A combination of all of the above concepts may reduce the parts count significantly and could remove more than 10% from the mass of the base engine as well as making it cheaper and simpler to produce with a smaller package volume.

*There are
advantages in
improved structure
stiffness and reduced
design complexity
for tool access*

One possible embodiment of this approach is seen in accompanying figures showing a new engine architecture. Here one can see how the integration of the exhaust manifold into the monoblock allows the exhaust outlet to be moved down the engine which could benefit the packaging of the vehicle and how an under-port injector position is freer than is the case with conventional architecture.



Lotus' New Engine Architecture with monoblock and exhaust manifold integrated into one assembly

The embodiment also has a bonded sump and even from this rudimentary representation one can see how a much 'cleaner' engine configuration is obtained with the scope to reduce complexity. Such an approach could yield major benefits in engine construction in the future removing, as it does, two high-cost gaskets, the exhaust manifold, one set of critical fasteners and myriad minor fasteners together with the machining and assembly associated with them.

Jamie Turner, Paul Burke, Andy Balding and Kerry Osborne

Lotus Engineering

Alternative powertrains

As legislators set increasingly tight and complex emission controls, the auto industry continues to pour billions of dollars into the alternative fuel tank.

A walk round the Detroit Motor Show at the beginning of January revealed that even North America has decided the time has come to conserve fuel — a move that will have a significant impact on powertrain development over the next few years.

How engines will run, what they will use as fuel and what sort of residual they leave behind is taxing the ingenuity of powertrain engineers around the globe.

Take Ford's Escape Hybrid E85. It is the world's first hybrid vehicle capable of operating on blends of fuel containing as much as 85% ethanol, a renewable fuel that can be produced from American-grown corn or sugar beets. Ethanol use releases no fossil-based CO₂ so its use as a fuel in place of petrol reduces the release of greenhouse gases.



Ford Escape Hybrid E85

"This innovative research programme could lead to breakthroughs to significantly reduce our nation's dependence on imported oil while also helping to address global climate change," said Anne Stevens, COO, Ford America.

Ford has two full hybrid electric vehicle models on the road today — the Escape Hybrid and the Mercury Mariner Hybrid — and plans to increase production capacity to 250,000 hybrid vehicles a year globally by the end of the decade. Ford will also produce up to 250,000 ethanol-capable vehicles this year, including the F-150 pickup truck, Crown Victoria, Mercury Grand Marquis and Lincoln Town Car large sedans.

Ford buys all of the hybrid transaxles it needs from Aisin, a member of Toyota's supplier group. Toyota is regarded as the industry leader in hybrids.

Latest to join the hybrid revolution is PSA Peugeot Citroën, the French company unveiled two demonstrators featuring a diesel-electric hybrid powertrain, the Peugeot 307 and the Citroën C4 Hybride HDi.

Average diesel consumption for these two cars is 3.4 litres per 100 kilometres (83mpg), with 90 grams of CO₂ emitted per kilometre, tank to wheel — a record for compact cars. PSA claims this is some 25% better than a similar vehicle equipped with a petrol hybrid system, or as much as a litre per 100 kilometres in combined urban and motorway driving.

PSA Peugeot Citroën's Hybrid HDi technology comprises a 1.6-litre HDi diesel engine, a particulate filter system (DPFS), Stop & Start system, an electric motor, inverter, high-voltage battery pack and dedicated control electronics. The cars are also equipped with an electronically managed manual gearbox.

Mercedes-Benz also chose the unlikely setting of the Detroit auto show to unveil its BLUETEC diesel technology which, it claims, produces the cleanest diesel engines in the world. BLUETEC brings together the best of existing diesel technology, such as, oxidising catalytic converters and particulate filters and adds a new one; injecting urea into nitrogen oxide which reduces NOx levels by up to 80%.

But, whatever else happens, hybrid systems will be present both in today's petrol or diesel-powered hybrid cars as well as in tomorrow's fuel cell vehicles. In Toyota's Fuel Cell Hybrid Vehicle (FCHV) the fuel cell stack replaces the internal combustion engine as the main power source and is combined with a secondary battery that stores and supplies electricity for propulsion.

In both cases, the hybrid system maintains precise control over the distribution of power and makes it possible for the main power plant to operate within its most efficient range.

The Toyota Hybrid System (THS) was the world's first mass-production hybrid and remains capable of achieving outstanding fuel economy and low tailpipe emissions. Hybrid vehicles are now on sale in Japan, Europe and the United States.

Comparison of CO₂, NOx and PM emissions from the practical power sources currently available clearly shows hybrid systems to be the best — particularly bearing in mind they require no new infrastructure and have no driving range problems.

Hybrid technology has gained widespread customer acceptance. Toyota's global cumulative sales of hybrid vehicles have totalled well over 100,000 units.

The THS unit consists mainly of a specially developed, high-expansion ratio, 1.5-litre petrol engine, a compact and high-torque electric drive motor; and a separate generator.

It works in conjunction with a bank of advanced nickel-metal hydride batteries, which store and supply electricity for propulsion.

The various mechanical elements of the THS are connected by a power splitting device, in the form of a planetary gear set which enables the petrol engine output to be divided between driving the wheels and turning the generator.

Feature

The key to the efficiency (and thus the reduced emissions) of the THS is the electronic control of power flow between the mechanical and electrical elements to ensure that energy is conserved at all times.

The main function of the petrol engine is to drive the wheels but any excess output is channelled to the generator from where it can be used either to re-charge the batteries or power the electric drive motor. Under normal running the ratio of delivered power between the petrol engine and the electric drive is controlled for maximum efficiency. If necessary the batteries supply extra power, via the electric drive motor, for manoeuvres such as hill climbing or overtaking.

In particular situations where the petrol engine cannot run efficiently or where it would produce relatively high emissions — for example, at low speed, travelling downhill or when standing still — it is switched off altogether.

During deceleration or braking, the energy flow through the drive motor is reversed to act as a generator and convert the vehicle's kinetic energy into electrical energy to be stored in the high voltage battery pack.

The launch of the THS-C system in the popular Estima (Previa) MPV represents a major step forward for hybrid technology. Not only has Toyota overcome a technical challenge, due to the weight and size of the MPV body but also the design opens up a whole new range of vehicle uses.

In the first instance, the Estima Hybrid is an environmentally friendly, family lifestyle vehicle with a 'go-anywhere' capability. But, like most MPVs, it can be adapted to suit the owner — perhaps as an office, a medical vehicle, a camping van or for outdoor sports.

Here the Estima Hybrid has one major advantage. It can use the hybrid system to generate its own power, up to 1.5Kw at 100v A/C — enough to power medical equipment, a small office, a microwave or even a hairdryer.

The THS-C Hybrid System uses a 2.4-litre, VVT-i petrol engine combined with two electric motors and a power splitter to control energy flow.

Toyota claims the Estima Hybrid achieves a fuel efficiency of twice that of many MPV-style vehicles of the same class. Fuel consumption is 5.6 litres of petrol per 100km (50.4mpg) and its clean emissions contain hydrocarbon (HC) and nitrogen oxide (NOx) levels that are more than 75% below the level specified by the 2000 Japanese standards.

Toyota's third hybrid system is called Toyota Hybrid System-Mild (THS-M) which the company says is a simple, easy-to-adapt hybrid system ideal for application in many types of cars and can be fitted to existing models. It has already been introduced in the Crown THS-M which went on sale in Japan last year.

The THS-M comprises three main components; a small motor/generator connected via an auxiliary drive belt to a high-efficiency petrol engine, a compact 36v secondary battery for power supply to the motor and a control unit. When the vehicle stops, the system goes into "idling stop" mode, automatically shutting down the petrol engine. To get moving again, the electric motor provides the initial drive force and re-starts the petrol engine.

The THS-M improves fuel efficiency by about 15%. When combined with a direct fuel-injection petrol engine, the system achieves 50% lower level emissions than those set for 2000 by the Japanese government.

Back at Ford, Nancy Gioia, head of sustainable mobility technologies & hybrid programmes, said, "Researchers are applying some of the best expertise in the industry to hybrid power controls, flexible fuel operation and exhaust after-treatment."



Ford Hybrid E85 engine

"We're working on the whole system, from the fuel tank through to the tailpipe, to optimise fuel efficiency and lower emissions."

Whatever the outcome of research into alternative power sources, the consensus is that the internal combustion engine will be with us for some time, although it will not ultimately rely on petrol or diesel as fuel.

Jean Botti, business line executive for powertrain at Delphi Corp. said: "Currently a lot of our resources are put into further developing direct injection for gasoline engines and next generation common rail for diesels. But we are also very excited about plans we have for fuel cells used as an auxiliary power unit for cars — coupled with an internal combustion engine."

"We feel this is a very important development for the near future and we are getting some very good results. There are still however, a lot of benefits to be gained from direct injection and common rail so we are pushing ahead with those technologies."

Source: Chris Wright , just-auto.com editorial team

2006MY Lotus Elise and Exige - auto industry first application of ProBax™ seating technology

Lotus Cars has become the first automotive OEM to enhance comfort by the introduction of ProBax™ seating technology on its 2006MY Elise and Exige models.

Working closely with NuBax, owners of the patented ProBax™ design, and with input from numerous departments from Lotus Engineering, a development programme has been completed in less than twelve months to deliver homologation-compliant seats for all world markets for the start of 06MY Elise production in August '05.

Initial interest in ProBax™ technology was sparked following a conversation with engineers at a PAG company, for whom Lotus was completing a proposal for an engineering project. NuBax had visited the Ford subsidiary to explain the ProBax™ concept, and by chance Lotus was searching for a way to improve the seating provided for its many CAD designers. Days lost due to back problems are a significant issue for this group, and the ProBax™ concept appeared to provide a solution to this costly problem.

The initial meeting with NuBax took place in September 2004, when engineers, senior managers and the Company Nurse listened to the NuBax presentation and experienced the concept for themselves sitting on “*demonstrator cushions*”. Despite initial scepticism, and running contrary to all logical expectations, there appeared to be something in the ProBax™ concept worth further investigation. It had rapidly become apparent that the concept could be applied to the seats in Lotus vehicles themselves, and so a scrap Elise seat was made available to NuBax to create a demonstrator “*concept*” seat.



ProBax™ team

When NuBax founder Donna Jackson — inventor of the ProBax™ concept and a Texan with many years of experience in prosthetics — left Lotus she freely admits to uncertainty how her design could be applied to such a minimalist seat. But behind this doubt was an exciting challenge: if the technology could be applied successfully to the Elise seat, then it would certainly be feasible in any other OEM's applications.

Jackson returned to Lotus in October for further discussions and carrying the “*demonstrator seat*” for Lotus review. Although very brief and focusing only on seat comfort, the initial Lotus appraisal was positive. On leaving Lotus, NuBax found itself with two sets of standard production seat parts and the triple challenge of improving Elise seat comfort and substantiating their claims of increased venous blood flow — whilst still complying with the Elise occupant “*H*” point.

The patented ProBax™ design maximises venous blood-flow from the lower limbs, in addition to “*stacking*” the spinal column correctly in the position assumed when standing upright. This (lordotic) posture is achieved by providing support for the two weight-bearing points of the pelvis (ischial tuberosities), hence rotating the pelvis fractionally forward. In turn, this relieves pressure on the gluteus and hamstrings, minimising restrictions to the venous blood-flow and counteracts the usual bowed (kyphotic) posture that conventional seats commonly create.

For conventional car seats, the desired pelvic rotation may be achieved using a shaped foam insert introduced into the B-surface of the existing cushion. This means that for most OEMs, ProBax™ technology can be introduced into existing seats without the need for styling changes. For the Elise however — where vehicle occupants typically sit on less than 20mm of foam, as dictated by the occupant package — the implementation has followed a different path.

For Elise, implementation of the ProBax™ design came via a “*Y*” shaped foam, twelve millimetres in thickness and of a carefully selected density, as an additional piece placed over the cushion foam and running up the centre of the squab. Whilst the form of this insert is essentially unchanged for 06MY production seats, the first prototype seats delivered to Lotus had been built away from the Lotus Trim Shop and with no input to seat style from Lotus Design. Despite these factors, however, a series of back-to-back blood-flow tests were arranged to investigate the value of the ProBax™ concept.

Conducted in late January 2005, the tests were devised by Texan cardiovascular surgeon Dr. Jon Senkowsky and conducted at Lotus by Vascular Technician Mike Raulerson. From a disarmingly innocent request for help in seat testing, twenty-nine Lotus “*volunteers*” ventured to a partitioned corner of Vehicle Workshop 1, where initial surprise at being asked to change into one-size-fits-all medical paper shorts was quickly replaced by shock as Raulerson thrust a medical probe deep into the groin of each volunteer to make the required measurements! It is testament to the long-suffering nature of Lotus employees that, having had

Feature

chance to see what was involved, not one “volunteer” refused to take part in testing, and no instances of physical violence towards the test organisers were recorded.

Using an Exige and an Elise fitted with conventional (05MY) and prototype ProBax™ seats, venous blood-flow measurements were taken from male and female subjects selected to cover a wide range of heights and weights. Additionally, subjects were asked to rate the two prototype ProBax™ seats for static comfort. Following analysis, the results of these tests demonstrated a significant increase in venous blood-flow for the two seats, a preferred direction for comfort was clear, and it was decided to progress the ProBax™ concept further. Not least, input from Lotus Design and confirmation of H-point compliance was urgently required.

With support from Purchasing, Lotus’ production seat foam supplier responded swiftly to create a prototype cutting-tool to create sample seat foams of numerous densities. These were used to create seats of subtly different construction for dynamic testing to optimise seating comfort and H-point testing to ensure homologation compliance. Design themes from Lotus Design were adapted where necessary to work with the ProBax™ concept, whilst support from the Production Trim Shop ensured a feasible seat for production.

A wide range of assessors then conducted numerous dynamic assessments over a pre-set route, with several assessments over longer weekend trips. Input from Lotus Vehicle Dynamics department ensured that the quest for comfort had not compromised the seat for when the car was driven on the limit. The opinions of durability vehicle drivers at Millbrook Proving Ground — in whose vehicle a prototype seat had been fitted — were canvassed and a further visit from Donna Jackson ensured the ProBax™ concept was being correctly incorporated. Numerous H-point tests were undertaken to reconfirm compliance with European H-point and Federal H-point was met. By late July, standard and sports seats were legally compliant for all markets, production feasible and ready for series production.

*Design themes
from Lotus Design
were adapted where
necessary to work
with the ProBax™
concept*



ProBax™ seats

Today, 06MY Elise and Exige seats are in series production, delivering cost savings when compared to previous seats and receiving positive reviews for comfort from the automotive press in Europe and the US.

Looking forward, Lotus is working to develop engineering consultancy opportunities by introducing NuBax to other automotive OEMs.

The attractions for other manufacturers are obvious. Firstly, comfort in all seat types can be improved, particularly in compromised seat packages such as third-row seats in MPVs. Secondly, in a typical “Performance through light weight” Lotus solution, the enhanced anatomical design of the seat permits weight, cost and build-time savings through the deletion of adjustable lumbar systems. Two large global OEMs are already expressing serious interest in the ProBax™ concept.

And what of the Lotus CAD designers with their long-suffering backs?

Norfolk chiropractors can breathe a sigh of relief. The designers still sit on the same seats they had twelve months ago...

John Hall

Toyota sets out global vision for growth

Toyota is a company going from strength to strength and could overtake General Motors as the world's biggest vehicle producer this year. At the company's recent opening of a new Toyota European R&D facility, Tokuichi Uranishi, Toyota's global sales and marketing VP set out some details of Toyota's global vision. Chris Wright caught up with him.

It's pretty much expected that Toyota will take over from General Motors as the number one purveyor of automobiles, any time now.

It's not far behind in terms of sales but already light years ahead in terms of cash in hand, unhampered by the General's massive pension and healthcare commitments, back home on the range.

In typical Japanese style, Toyota executives are supremely modest when it comes to blowing their own trumpet. *"We have not so much a long term plan but a global vision,"* says executive vice president, Tokuichi Uranishi, head of Toyota's global sales and marketing.

That global vision includes a worldwide market share of around 15% by 2010 with growth at home and in emerging markets but the other big regions are not being ignored.

Toyota Motor Europe (TME) has just opened its new EUR130m research and development centre in Brussels, hot on the heels of its new joint venture car plant with PSA Peugeot Citroen which began assembly last year in the Czech Republic.



There are more plans in the General's back yard as well. Uranishi said Toyota will almost certainly utilise spare capacity at Subaru's Lafayette plant in Indiana, USA.

Subaru has a 100,000 production capacity in the United States and has some spare. *"We will be looking to see how best we can use the additional capacity,"* said Uranishi, during the opening ceremony for the new R&D centre.

He confirmed the companies are studying a plan to build either a car or an SUV at the plant where Subaru hopes to offset the loss of a small Saab crossover based on the Tribeca that was to be produced in Indiana.

General Motors cancelled that plan last October when it sold its 20% stake in Fuji Heavy Industries Ltd., Subaru's parent company. Toyota later acquired 8.7% of Fuji Heavy.

There is also the possibility of increasing production further. The plant, originally a joint venture between Subaru and Isuzu, has capacity for 240,000 units but Subaru currently uses less than 50% of this.

Isuzu sold its 49% stake to Fuji Heavy in 2003 but continued to build its Rodeo pickup and Axiom SUV there until July 2004. Subaru currently builds Tribeca at Lafayette along with the Legacy/Outback and Baja cars.

Uranishi added, *"We are also looking at how Toyota and Subaru can work together on vehicles and technology in the future but, in the short term, additional North American capacity is of most interest to us."*

Uranishi said that Toyota was also interested in producing a low-cost sedan for emerging markets, very much like the Logan, a collaboration between Renault and its Romanian affiliate, Dacia.

"I would not want to compromise Toyota's reputation as a technology and environmental leader but, in Daihatsu, we have a sister company that is very good at producing low cost vehicles. There is a demand for vehicles such as the Logan in emerging markets and there is big potential in the segment – we are very interested in it."

"We are also looking at how Toyota and Subaru can work together on vehicles and technology in the future, but, in the short term, additional North American capacity is of most interest to us"

Feature

Uranishi, however, ruled out introducing Scion to Europe as a third brand to help lower the age profile of customers to the Toyota and Lexus brands. *"Scion is a brand for young people but it would not be particularly cheap so we have no plans to introduce it in Europe."*

Toyota Motors Europe (TME) will increase its purchasing spend with European suppliers to EUR4.5bn by the end of 2007, up from EUR4bn last year and just EUR1.2bn in 1999.

European manufacturing chief Alan Jones said, *"Our suppliers are key partners. Around 60% of the cars we sell in Europe are made in Europe and over 90% of the content of those vehicles comes from Europe – from our engine and transmission plants in the UK and Poland but also from our European suppliers."*

TME has 289 suppliers based in 451 European locations. As well as the Brussels headquarters, TME also has eight production centres in the UK, France, Turkey, Poland and Czech Republic, its ED2 design centre in the South of France, Formula One HQ in Germany plus national marketing and sales companies in 48 countries and nearly 2,900 dealers.

Jones, TME's executive vice president manufacturing, said the new R&D centre would also bring together many other elements such as purchasing, technology and design which would be of great benefit to the automaker's European manufacturing operations.

The centre's main responsibility is to ensure technological developments are matched to European driving conditions, standards, legislation and tastes.

"Europe is the biggest market in the world for diesel engines and the work carried out at the new facility on these engines will be very significant for the future," Jones added.

Belgium was chosen for the new R&D centre because *"we like it here,"* said Jones. *"Our European head office is in Brussels, we have parts and logistics centres in Diest and Zeebrugge, we have over 2,600 employees in Belgium and our investment here is around EUR418m."*

"It also offered exactly what we needed; a location attractive to potential employees, a highly skilled workforce, good local universities and institutions plus we are close to our manufacturing centres and suppliers."

TME has achieved record sales in each of the past nine years selling 964,000 vehicles in Europe last year relating to a market share of 5%.

Uranishi said that this year Toyota hopes to pass the one million mark and reach 1.2million by 2010 — a market share of 6.5%.

Source: Chris Wright , just-auto.com editorial team



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