proActive

The official industry newsletter of Lotus Engineering

Issue 5
December 2004

Germany: BMW reveals first details of new 3 series

Lotus Vehicle Safety Integration Engineering

Welcome

Today there are a number of key business drivers challenging the role of the Materials Engineer, including the End of Life Vehicle Directive, NCAP testing, Pedestrian Impact Legislation, and Emissions Legislation. These factors have combined with the more usual decision criteria of quality, durability, and environmental performance to influence the final material choice and manufacturing feasibility of a project.

The Materials Engineering group at Lotus is split into the three main disciplines of Metallic materials, Non-metallic materials (including polymers and composites), and Joining Technologies. Our engineers have extensive knowledge and expertise in these technologies and their application on new and innovative vehicle architectures. This expertise has been gained through involvement in the design and development of several lightweight vehicle programmes and involves an independent approach to the selection of appropriate material and joining technologies for the optimum solution.

This edition of proActive will feature Metallic Materials and Joining Technologies. Application examples of these technologies in the successful delivery of vehicle engineering programmes will be discussed. Non-metallic materials technologies will feature in the next edition of proActive.

Jason Rowe

Chief Engineer – Materials and Process Technologies

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Germany: BMW reveals first details of new 3 series

BMW has announced first details of the new 3 series range to be launched in early 2005.

The fifth generation models will all have a standard six-speed manual gearbox with six-speed automatic optional. Topping the range is the 330i with the new lightest-in-class six-cylinder engine with 'valvetronic' induction system, as recently introduced in the 6-series line.

Six-cylinder models will also include a 218bhp 325i. The new range will also feature a two-litre diesel and a two-litre petrol variant at launch.

The engine in the new 150bhp entry-level 320i is based on that of the outgoing 318i, but with enhancements to the induction and exhaust systems.

Further four-cylinder variants will follow during 2005. As usual, BMW will launch the four-door sedan first, while replacements for the coupe, cabriolet, Touring (wagon) and M3 sports models can be expected over the next year or so.

Six cylinder models will have a new DSC+ system. Effectively an evolution of the familiar DSC traction control system, DSC+ offers a number of features including 'brake standby' that pre-tensions the brakes when the driver quickly removes the pressure from the accelerator pedal. 'Soft stop' modulates the brake application to prevent the nose of the car from diving when travelling slowly and a 'start-off assistant' (hill holder) uses the clutch to prevent the car from rolling back on a hill start. A 'brake detector' ensures the discs are kept dry and responsive on wet roads.

BMW is also making its 'active steering', launched with the 5-series, available for the first time in this class as an option on six-cylinder models.

Like the 5, the new 3 has double-joint spring strut front suspension made completely of aluminium, minimising the unsprung mass of the car and reducing road noise. The new five-arm rear axle, first seen on the 1, is claimed to provide excellent ride comfort but, because run-flat tyres are now standard, we'll

reserve judgement on that after experiencing the harsh-riding 1-series.

The new 3 series body is 25% stiffer yet lighter than that of the outgoing model thanks to a new joint and crossbar arrangement for the car's load-bearing structure.

Six airbags are standard, including curtain head airbags for front and rear occupants, and the car is expected to receive a five-star Euro NCAP rating. It is also one of the first cars in the world that is fully prepared for the rigorous side impact requirements in North America as well as the US high-speed rear impact test.

'Brake force display' is standard for the first time on the 3 with its two stage brake lights. The stop lights illuminate normally in average driving conditions but during an emergency stop or when the ABS braking cuts in, the area of brake light illumination increases to warn those travelling behind.

Newly developed run-flat tyres allow to be driven for up to 150 miles at 50mph with up to four punctured tyres.

The new 3-series is larger than its predecessor and now measures 4,520mm (+49mm) in length, 2,760mm (+35mm) in wheelbase, 1,817mm (+78mm) in width and 1,424mm (+9mm) in height. Rear occupants benefit from an increase in head, shoulder, elbow and leg room.

BMW's iDrive system is now optional, in conjunction with sat-nav. Keyless access and engine start have also been added.

Source: just-auto.com editorial team

Germany: Ford plans industry leading platform consolidation

Ford of Europe will consolidate passenger car production from four platforms to two to reduce manufacturing costs.

According to Automotive News Europe, the next generation of upper-medium vehicles - including the Mondeo, Galaxy minivan and a crossover vehicle to compete with the Toyota RAV4 - will be built on a longer-wheelbase version of Ford's C1 lower-medium platform. The extended platform is code-named EUCD.

The basic C1 platform introduced in 2003 already is the basis for the new lower-medium Ford Focus, Focus C-Max, Mazda3, Mazda5 and Volvo S40 and V50.

> Ford could save "hundreds of millions" by not having a separate upper-medium platform

All small cars, from the Ford Fusion and Fiesta down to the Ka and possibly even lower, will be developed on Ford's B platform, known as B2E. Mazda is leading the work on that programme.

Ford hopes to reduce manufacturing and development costs on its European line-up by simplifying the basic underpinnings of its cars and making them more flexible to support more niche vehicles. Ford officials refer not to platforms but architectures, which at Ford consist of a "store" of components and systems the brands can choose from.

The EUCD plan has ramifications for Ford's other brands, including Jaguar, whose X-type shares many of its components with the current Ford Mondeo.

Sources say the next generation X-type could be built on the extended C1 platform.

"There are not many platforms that are that flexible," said Nigel Griffiths, analyst for Global Insight in London. "If they crack it, it will become a sort of benchmark for other manufacturers to follow, I suspect."

Griffiths estimated Ford could save "hundreds of millions" by not having a separate upper-medium platform.

Currently, PSA is Europe's leanest car maker in terms of platforms. The French group has nearly completed its consolidation of Citroen and Peugeot brand car lines on only three platforms.

Ford's current plan includes a new Ford-brand crossover vehicle - probably a Toyota RAV4 competitor with five doors and all-wheel-drive - that will be made on the extended Focus platform and built in Genk, Belgium, alongside the Galaxy and Mondeo. Also being considered are more offerings in the sub-Fiesta minicar segment where Ford now only offers the three-door Ka.

On the larger platform, the Galaxy will be the first vehicle. The second Ford product off the larger platform will be the crossover in the second half of 2006, followed by the Mondeo replacement in early 2007.

Source: Just-auto.com editorial team

UK Analysis: Forecasters have capacity concerns for Europe

SupplierBusiness.com talked to the leading global forecasters to find out where they see 2004 headed, in terms of total industry volume in Europe. The forecasters discuss capacity utilization, implications of model mix, and the impact of rising materials prices.

Global Insight: Western European production flatlining, but rising material costs not expected to impact demand

Total industry car production in Western Europe is flatlining, according to Nigel Griffiths at forecasters Global Insight. "It doesn't mean that it's got a cardiac condition, but basically if you look at seasonally adjusted production rates, it has been remarkably stable since the late summer of last year", says Griffiths.

Production has stayed stable at an annualised 14.9m passenger cars in western Europe overall, with increasing exports off-setting the losses in the domestic market caused by relatively weak demand and growing import competition.

Export growth has been up due to fresh products, such as the BMW X3, volume growth for the Volvo XC90 and the Volkswagen Touareg and Porsche Cayenne models.

Griffiths is optimistic that exports will continue to support production into 2005.

Exports to North America have been largely hedged for the German manufacturers, says Griffiths, and the hedges “don’t start to unwind until the second half of the next year”, so the pricing need not be changed until then.

Global Insight expects production of new cars in Western Europe to grow in 2004 and 2005. Some of the potential weakening of exports in 2005 is expected to be taken up by European demand - the European economy is expected to see faster economic growth in 2005.

One potential threat to European production volumes in 2005 is higher raw material costs feeding through into new car prices, which could depress demand.

Griffiths says that the additional increase in raw material prices will have some effect on car prices, but that in the current compe titive market environment, it would be difficult for car makers to pass price increases on.

Griffiths says that in Western Europe pricing growth has fallen back to a third of the rate of inflation - real car prices are declining. “On top of that you’ve got very strong incentives and discounting”, he says. The growth of Toyota and the Korean manufacturers in the European market will help to cap the room for price increases.

Griffiths says that overall, rising raw material and oil prices are likely to have a relative minor impact on prices in the marketplace, and therefore are likely to have only a small impact on demand.

“By the time [higher costs] get right through the supply chain, it’s actually quite a small number”, says Griffiths. “You would have to have a very large customer elasticity to get a bit dent in the market”.

PricewaterhouseCoopers AUTOFACTS: BMW and DCX grow while Fiat and MG face declines

Within the European production total the biggest gains are expected to be made by the BMW group, according to Michael Gartside at PwC AUTOFACTS.

The addition of the BMW 1 Series is expected to provide a 15.8% growth in 2004, and another 12.3% in 2005. DaimlerChrysler is also sees strong gains in 2004 and 2005.

Rising small car production at Smart will boost DaimlerChrysler volumes.

Smart is expected to account for almost 230,000 vehicles in 2005, compared with 127,400 in 2003.

PwC also expect Porsche to continue to grow their volumes with their renewal of the Boxster.

One of the losers is expected to be the Fiat group, with the Fiat brand itself taking the brunt of the decline. Fiat brand production is expected to fall below the 1m mark in 2004 to 963,000, and fall further to 938,000 in 2005.

Among the other manufacturers Honda is at a weak point in its model cycle in Europe, and will see a drop in production, while the MG Rover group’s failing model range is expected to result in a decline in volumes by over a quarter between 2003 and 2005, says PwC AUTOFACTS.

Polk Marketing Systems: Continuing price pressure and GM capacity review

Thomas Mawick, Autos Analyst at R L Polk Marketing Systems in Germany, expects growth in west European production increase of 2.4% in 2004. “Shipments of German car producers to the US will face a slight decrease this year”, says Mawick, but “export dynamism to Asian and east European markets are still tending to pick up”.

Mawick is forecasting a further increase of production to 15.32m units in western Europe in 2005, again driven by exports. Mawick says the that the proliferation of new models across more and more segments and niches means that “price pressure will at least continue, if not sharpen”.

“Low consumer confidence will certainly not help”, he says.

Mawick expects that GM Europe will need to review its capacity. Even in the Astra, although “a very good car”, will probably face relatively low demand as “the compact segment is characterised by a full model offering and extensive competition”, says Mawick.

CSM Worldwide: Light commercial vehicle production moving to eastern Europe

Mark Fulthorpe, director, European vehicle forecasts at CSM Worldwide, identified a shift in light commercial vehicle production to central and Eastern Europe as one of the biggest changes affecting the industry in Western Europe in 2004 and 2005.

Ford has shifted some of its full-sized Transit production from

Genk to Turkey and the growth of the Transit Connect, which is only produced in Turkey, is adding to the volume shift.

In addition Volkswagen is producing its new Caddy van at Poznan in Poland.

“Poznan is also taking on some of the sourcing of the T5 [Transporter] van”, says Fulthorpe.

Within Western European car production, Fulthorpe agrees with other analysts that Fiat faces the biggest challenge. “Fiat stands to lose the most” production volume in 2004 and 2005, says Fulthorpe.

Fiat is almost out of the D segment, he says, with just the Alfa 156 left competing in the upper-medium part of the market.

> *“BMW and PSA are currently operating at 90%+”*

Further down the market “Fiat is under pressure, not just from the growth of DaimlerChrysler and BMW in the C-Segment, but also the growth of Toyota”, he says. “It is going to take them into a head-on battle in the B and C segment”.

Fulthorpe says that the “remarkably resilient” performance of the Ford Focus as it approaches run out is also a challenge to Fiat.

JD Power-LMC Forecasting : Overhang of stock - capacity utilisation low at Fiat

Arthur Maher at forecasters JD Power-LMC Forecasting services says that his analysis “suggests that we finished 2003 with too many cars. We estimate that stocks rose by 106,000.”

That overhang has not gone away during 2004, says Maher. Total European car build was up to 340,000 units (+4%) in the first half of 2004, Maher estimates.

Most of the growth took place in Eastern Europe up 200,000 units (+30%), with volumes up 100,000 units in Western Europe.

Maher says that there was a relatively modest level of de-stocking in the first half, and estimates the third quarter of 2004 saw no de-stocking. Maher expects this stock overhang will persist “we envisage stocks moving up a shade in Q4, despite Jaguar and Fiat cutting back on build”, says Maher.

That leads JD Power-LMC Forecasting to expect that a reduction in stock will depress production in 2005. However, because of important new models coming through, such as the Citroen C4, GM Astra, Renault Modus, Volkswagen Golf Plus and the new-segment model for PSA and Toyota, progress on de-stocking may be slow, says Maher.

Maher estimates that European capacity utilisation is currently 78%, two percentage points higher than 2003. But the contrast between the best performers and worse performers in capacity utilisation is wide.

CHINA: Government to demand more fuel-efficient vehicles

China will demand automakers produce more energy-efficient cars in order to reduce fuel consumption, a senior engineer at China Automotive Technology & Research Center, which is drafting the new rules, told XFN-Asia, according to AFX News.

The engineer, who asked not to be named, said China will implement the new restrictions in two phases, the first one starting in July in 2005, and the second phase starting in January 2008.

Although he did not provide any details about the standards automakers will need to meet, he said most manufacturers of M1 passenger cars - passenger cars with a weight below 3.5 tons and up to nine seats - will be exempt from the first phase. However, he said that most M1 cars on the road today will not be able to meet the standards set for the second phase.

Automakers, however, will have sufficient time to engineer the necessary technology improvements on engines and transmissions prior to 2008, he said.

The report said the restrictions are likely to impact producers of fuel-hungry sports utility vehicles and benefit manufacturers of more economical sedans.

Source: just-auto.com editorial team

The Continuing Importance of Chassis Engineering

The main pressures on vehicle designers and engineers continue to be safety and exhaust emissions, together with fuel economy (except in North America). However, intense competition, especially towards the top of the market, means that comfort and sheer ease of driving are also important considerations. They can make the difference between winning and losing the customer. Consequently, a great deal of engineering effort has lately been devoted to the chassis - in its modern sense of suspension, brakes and steering - in a search for unparalleled levels of ride comfort & quietness, control and dynamic safety. Jeff Daniels reports, in this extract from an exclusive just-auto research report.

Historical

In the early days of vehicle design and manufacture, the chassis was the frame above which the body was mounted, and below which the axles were mounted by means of their springs, together with any associated steering and braking systems.

During the 1920s, pioneers including Budd in the USA and Lancia in Europe began to study the implications of eliminating the chassis frame, attaching the wheels - whether mounted on axles or independently - directly to the body. It quickly emerged that to achieve similar orders of stiffness in bending and (especially) in torsion, a load carrying body could be made lighter and more compact than an unstressed body mounted on a chassis frame. By the 1950s the stress-carrying "unitary" body had become the industry standard. The terms "chassis" had not disappeared, but had rather been transferred to those systems between the body and the road surface - the suspension linkages, springs and dampers, and the wheels themselves - together with the closely associated steering and braking systems essential for control of the vehicle.

Some observers regard chassis systems and suspension systems as synonymous, but this disregards the interdependence of suspension, steering and braking systems and the fact that they are integrated to an increasing degree, especially at the electronic level. It may also be argued that even in the early days of motoring when complete chassis were delivered to coachbuilders for body installation, the steering and the brakes (such as they were) were already installed.

Current scope

In present-day terms, therefore, the terms "chassis engineering" or "chassis systems" embrace a hierarchy of technologies and features that may be outlined as follows:

Suspension: embracing the choice of basic geometry for optimum wheel location, the mounting of suspension members to the body (including the use of sub-frames), the springing medium and the provision of damping of vertical wheel movement.

Steering: the optimisation of front suspension geometry for steering, the choice of steering system, the provision of power assistance, the satisfaction of safety requirements, and the provision of "augmented stability" through interaction with the braking system.

Braking: the choice of friction system, the design of the operating linkage, the provision of servo assistance, the satisfaction of safety requirements, the provision of anti-lock braking and other enhancements such as emergency brake assist.

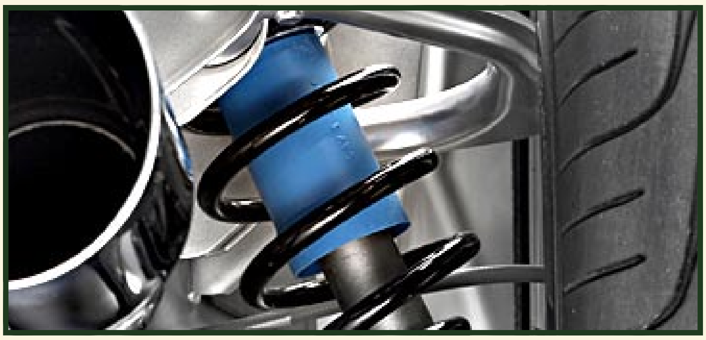
Wheels and tyres: choice of wheel and tyre size, choice of wheel material and tyre configuration, choice of spare wheel configuration or "run flat" technology.

Other Engineering Constraints

As noted in the outline above, chassis engineering is subject to many legislated safety requirements with profound engineering implications. Two examples are provided by the requirement (in almost all markets) to "split" the braking system in such a way that a single failure will not compromise safety, and the requirement that all steering systems (except in specialised vehicles with a low maximum speed) should consist entirely of mechanical linkages. In this latter respect, revised legislation will be needed, certainly within the EU, if "steer by wire" is ever to be acceptable.

While the main engineering considerations in the area of chassis systems are as outlined above, design is also subject to the "universal" constraints of cost and weight. Reducing chassis engineering cost is especially difficult in the light of consumer demands for ever better refinement and ride comfort, and for higher vehicle performance (placing greater demands on the quality of steering, handling and roadholding). Electronic systems today play an increasing role in chassis systems, and this trend will continue into the foreseeable future. Most electronic systems add new capabilities, but also cost.

The saving of weight in chassis system components, as discussed later, has more value than merely reducing the vehicle's mass and therefore improving its performance. Reducing the weight of



wheels, tyres, suspension components and most brake system components also reduces the unsprung mass - the total mass of all components between the road surface and the springs - and this improves both ride comfort and roadholding. Therefore much work has been done on reducing the weight of both suspension and brake system components, although to some extent these efforts have been negated by the recent tendency to fit ever larger and wider (and therefore heavier) wheels and tyres.

Significance to Vehicle

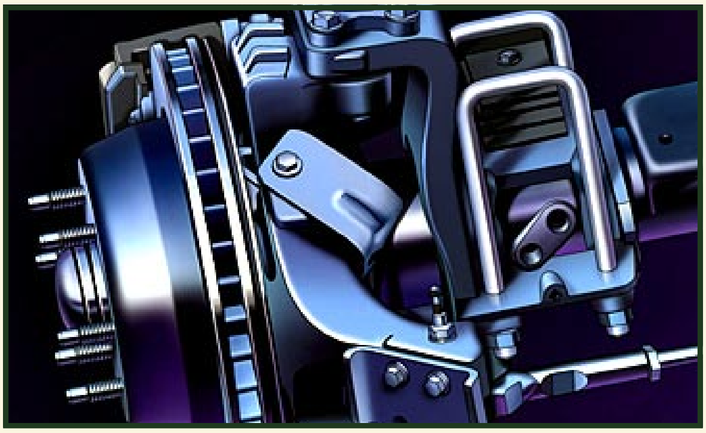
Chassis systems determine many of the fundamentals of vehicle behaviour and "character", in particular ride comfort and (to a considerable degree) noise levels on one hand, and the quality of steering, handling and roadholding on the other. These are not, by and large, the qualities that influence the decision to buy, which (leaving aside questions of manufacturer reputation) is largely dependent on external appearance, visible features and price. They are, however, aspects that (together with reliability) play a large part in determining customer satisfaction during vehicle operation - which may in turn influence the decision for or against a repeat purchase.

Especially in recent years, chassis engineering has provided one of the most effective means of determining the "character" of a vehicle. It has been shown that measures as simple as stiffening the suspension mounting bushes can significantly alter the subjective impression of steering response and handling, for example. This provides an easy and cost-effective means of differentiating between versions of a single model to match a range of customer expectations.

In the medium term, the increasing use of electronic systems in chassis engineering may provide an even easier means of adjustment.

Manufacturing and Supply Considerations

There is a clear division in chassis engineering between suspension, for which the VM usually retains total design and development responsibility, and steering and brakes, for which a significant degree of responsibility is passed to Tier-One suppliers.



Components for the suspension - mountings, arms and links, springs and dampers - are either made in-house (sometimes in specialised facilities) or more often, bought from highly specialised Tier-Two suppliers. This is especially so in the case of springs and dampers - although it is worth noting that Peugeot, which regards damper quality as crucial to chassis quality as a whole, still makes its own dampers in a special section of its Sochaux works.

Steering and braking systems, by contrast, are more often engineered by specialist suppliers working in close collaboration with the VMs. Many of these specialists, for example Akebono, Bosch, Delphi, Teves, Valeo and ZF, are extremely large operations in their own right (with interests extending well beyond chassis engineering), have a wide range of VM customers, and have helped to pioneer the adoption of modern technologies, from ABS to electric power steering to ESP.

The size of the market for OEM chassis systems may be gauged from the fact that 50 million light duty vehicles are manufactured, worldwide, every year. In chassis engineering terms that is 200 million "corners" since there has been a tendency, ever since independent suspension became well-nigh universal, to regard each wheel as being linked to is own chassis system (linkage, spring, damper, brake, and - at the front of the vehicle - steering). A modern trend is for "corners" (less wheels) to be supplied by Tier-One operations as complete sub-assemblies.

As the volume manufacture of light-duty vehicles has spread beyond the three main industrial areas, so these Tier-One suppliers have tended to expand their own operations, or to licence their technology, to extend their coverage to match. It is difficult to see how any new operation could now be created in serious competition with these existing and very powerful players. The Tier-Two operations associated with suspension parts, including springs and to some extent dampers are another matter altogether. Although this tier has seen some amalgamation in recent years, myriad small suppliers still exist and new ones are being created (or existing companies are adapting their product ranges) to satisfy demand in the emerging vehicle manufacturing areas.

It should be noted that at Lotus Engineering the responsibilities of the Chassis design group extend far beyond that outlined in this article. At Lotus the Chassis design group also takes responsibility for the Design, Layout and Package of the following areas as well as those mentioned in the article.

- The Fuel system
- The Cooling system
- The HVAC system
- The Powertrain mounting system
- The Powertrain Intake and Exhaust systems

Source: just-auto.com editorial team

Materials, Technology and Safety

The Metallics and Joining areas of Lotus Engineering are responsible for component manufacturing feasibility, design support, and materials specification. They specialise in recommending the optimum manufacturing process early in the design phase and support engineering throughout the vehicle development process.

These next sections discuss the use of metallic and joining technologies, the key drivers affecting technology selection, and give examples of successful applications.

Metallic Materials Technologies

Globally, the challenge for the automotive industry is to increase the fuel efficiency of vehicles, whilst improving safety, performance and maintaining affordability. Recent and future developments in metallic materials and associated processes have a significant role to play in achieving these objectives.

Over recent years both the steel and aluminium industries have recognised the importance of meeting the increased demands placed on automotive materials. This has led to the development of many new material types targeted specifically at the automotive sector. The metallurgy of such materials are often complex, and the materials themselves range from advanced high strength steels for improved crash energy management, to bake-hardenable aluminium skin materials for improved dent resistance in body panels.

The Metallics section at Lotus has the knowledge and experience to select the optimum material grade and associated process for a particular application, and to ensure manufacturing feasibility of all metallic components. This has been demonstrated on the Lotus VVA (Versatile Vehicle Architecture) project which optimises the use of some of the latest aluminium materials, process technologies, and simulation software available.

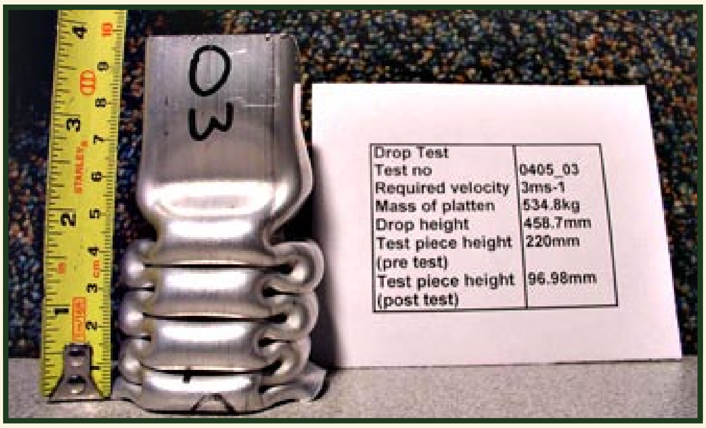


Fig 1: Crushed aluminium extrusion

One example of material optimisation is the extruded aluminium crush cans used on the VVA structure, which utilise a 6xxx series alloy with a specific heat treatment cycle. The metallurgy of this material has been developed to absorb higher levels of energy with improved crash performance. The structure/property relationship enables the material to crush without fracture as can be seen in Figure 1. The use of extrusions for this type of application enables the application of high strength alloy materials compared to pressed sheet grades. This particular alloy is air quenched which reduces component distortion and assists with achieving targeted dimensional tolerance requirements. Weight reduction is also possible for this application due to gauge optimisation and removal of additional joining flanges.

In addition to extrusion materials selection and manufacturing support, the Metallics group carried out manufacturing feasibility and materials specification for approximately 280 aluminium body panels for VVA. These complex panels in the structure are produced using conventional press forming methods and are technically demanding in terms of manufacturing feasibility. This is due to aluminium having reduced formability compared to steel and, therefore, reduced panel draw depth. This is exacerbated by aluminium “spring back” being twice that of steel. In order to achieve feasible panel design and reduce the risk for “problem” parts in production, Lotus utilised “Autoform” metal forming simulation software from the earliest stages in the design phase. This required the input of robust materials data from suppliers combined with in-depth press tooling knowledge. This combination is critical in order to achieve meaningful results, which are fed into the engineering and design team repeatedly as the design evolves to achieve a feasible part for manufacture. Figure 2 shows a simulation model of a door ring demonstrating problem areas requiring design changes

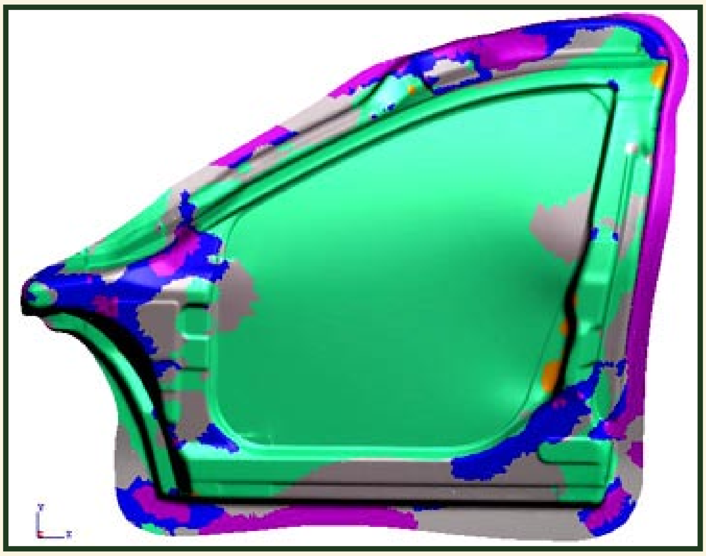


Fig 2: Autoform simulation of a Door Ring

(Red: cracks) (Orange: excess thinning) (Yellow: risk of cracks) (Green: safe) (Grey: insuff. stretching) (Blue: wrinkling tendancy) (Purple: wrinkles)

This iterative process has now been used on a number of vehicle projects at Lotus with excellent results, personified by the VVA prototype panels, produced with few difficulties to a high quality.

In addition to pressed and extruded components the VVA structure utilises twelve high pressure die castings. Process selection, feasibility and materials input was given by the Metallics group in support of these parts which were used throughout the VVA structure including structural corner nodes. High pressure die castings were used to achieve thin sections (minimum wall thickness around 2mm) and large surface areas whilst maintaining high levels of elongation. The castings were utilised to give improved body and point stiffness, dimensional tolerances, part integration, and reduced tooling investment. In addition, the high pressure die castings are exploited for use in crush zones of the body structure in certain instances.

With respect to future trends for metallic materials within the automotive sector, the drive is undoubtedly for lighter weight materials at lower cost. Such examples include die cast magnesium for inner body panels and hot formed magnesium pressings both of which offer significant mass reduction benefits compared to aluminium. Whilst magnesium die castings have already been used for inner panels on some production vehicles, the mass reduction potential comes at a price and will not be considered commercially viable outside of luxury and niche vehicles unless material and process cost is reduced. This can be achieved only if material, component and car producers such as Lotus work together to achieve further possible applications and increased demand.

Joining Technologies

This discipline at Lotus has traditionally focussed on adhesive technologies - the most notable example being the one-component heat curing epoxy material used on the Elise aluminium chassis. However, the varied nature of client projects has required a skills-base that now includes thermal, cold, and mechanical fastening techniques

Advances in current joining technologies are being driven by the use of new, lightweight materials and hybrid structures. The use of such materials has necessitated the development of alternative joining techniques to replace the more traditional technologies such as spot welding for BIW manufacture. These conventional steel welding processes are known to give rise to stress raisers, lowering the fatigue life of a joint and promoting stress corrosion, both which act to compromise vehicle safety.

The drive for lightweight structures leads to the requirement for lower gauge parts, whilst continuing to meet the ever increasing durability and safety performance requirements on new vehicles.

A riv-bonded BIW can provide an excellent combination of lightweight and high torsional stiffness and high-energy

Fig 3: Riv-bonded Structures

absorption. The crash stable adhesive works in harmony with the mechanical fasteners to absorb high levels of energy and minimum displacement of crush beams, increasing the potential for occupant safety in the event of dynamic impact.

In order to meet these stringent requirements it is becoming increasingly necessary to adopt a multi-joining approach to BIW structures, using a combination of different joining processes to meet the vehicle's targets.

The recent trend for aluminium vehicles has driven the use of new welding techniques such as laser welding. Such techniques often do not maximise structural efficiency, as a compromise needs to be made with the aluminium gauge to allow for the reduction in mechanical properties around the welded joint (known as the Heat Affected Zone).

Advanced cold joining techniques such as self-pierce riveting (SPR) and mechanical fastening techniques requiring only single sided access permit down gauging of the aluminium materials and offer the weight savings required by manufacturers. Such techniques also allow the joining of dis-similar materials and processes e.g. aluminium to steel or aluminium extrusions to aluminium die / sand castings. However, the use of mechanical fastening alone does not provide optimum joint performance for dynamic impact and torsional stiffness.

One of the biggest recent advances in joining technologies is in the performance of structural adhesives. The latest generation of structural adhesives has been designed to provide toughness and therefore directly contribute towards increased vehicle safety by increased energy absorption. Structural adhesives can provide excellent stiffness, strength and impact resistance and are increasingly used in primary structure applications.

Where once adhesives were considered only for low, niche

- Design
- Cost and Volume
- Weight
- Tooling Lead Times
- Performance
- Manufacturing Issues
- Legislation

The Metallics section at Lotus has the knowledge and experience to select the optimum material grade and associated process for a particular application, and to ensure manufacturing feasibility of all metallic components.

product volumes, they can now be found in higher volume products such as 5 series BMWs. The chemistry of the crash stable structural adhesives is suited to the conventional automotive production line. These adhesives typically cure at temperatures around 180°C and therefore the electrocoat process can be used to cure the structure without the need for a dedicated curing oven.

Whilst adhesives can now provide many structural advantages, there are major benefits to be had by combining this technology with a mechanical fastening technique as Lotus has done on the VVA structure. 'Riv-bonding' provides the advantages of each technology whilst at the same time eliminating some of the disadvantages. For example, the combination of SPRs and adhesive provides a joint with far greater peel resistance than bonding alone and at least three times the strength of riveting alone. In addition, the SPRs allow de-jigging of the primary structure before the adhesive is cured, holding the geometry and dimensions without specialist fixturing through electrocoat.

The continuing development of new lightweight and environmentally friendly materials such as thermoplastics will drive the requirement for further advances in joining technologies. Such technologies will be required to contribute towards the customer requirement for high standards of occupant and pedestrian safety.

Materials, Technologies and Selection

The role of the Materials Engineer is a complex one as the number of technologies available suggests. In selecting an appropriate material technology the Materials Engineer considers a long list of performance requirements. These requirements would include aspects such as: As an engineering consultancy dealing with most of the major OEM's the performance requirements that are rated highest include cost (investment), weight, mechanical properties, panel gap and flushness, and surface finish. These are in addition to certain key business drivers that they must also address and are explained briefly in the following sections.

Key Business Driver: Pedestrian Impact Legislation

An EU Directive on pedestrian impact (2003/102/EC) has been passed for the purpose of reducing the severity of injuries in the event of a collision between pedestrians and road vehicles. Implementing the requirements of the directive will take place in two stages, with Stage One to be completed by October 2005 and Stage Two to begin in September 2010. The focus of Stage Two will be on the test methods and criteria of the EEVC Working Group 17 (EEVC WG17). From these dates road vehicles can only be type approved if all models entirely meet all the requirements specified by the law.

The conflicting requirements between the functional needs of the vehicle and the requirements for pedestrian protection, particularly with Stage 2, represent a challenge to the vehicle architecture as well as the material technologies utilised. Softening pedestrian contact requires energy absorption to a very low force level in comparison to other crash and functional requirements. To meet the head impact criteria in the outer areas of the bonnet, degrees of softness are demanded that conflict with the normal requirements of the front end. Deformation of the wing or bonnet hinges by simply leaning on the vehicle or closing the bonnet will not be tolerated by the vehicle owner nor stress cracking in these parts or restrictions in terms of passenger safety by the manufacturer. Ignoring functional requirements in the interest of pedestrian impact will therefore not be possible.

Meeting the requirements of pedestrian impact legislation will be a particularly difficult challenge. However, the appropriate selection and application of materials technology can have a significant effect.

Key Business Driver: End Of Life Vehicle Legislation

The End of Life Vehicles Directive (2000/53/EC) came into force in Europe on October 21, 2000. It applies to cars, vans, and certain three-wheeled vehicles. Member States were to implement the directive by April 21, 2002. However, there were delays across Europe in implementation and the UK government began bringing the requirements of the directive into domestic law in November 2003.

The Directive's main requirements require Member States to ensure that:

- vehicle producers limit the use of certain hazardous substances in the manufacture of new vehicles and automotive components, and promote the recyclability of their vehicles;

Fig 4: Lotus Elise - Side Impact

- ELVs are subject to de-pollution prior to dismantling, recycling or disposal;
- treatment facilities operate to higher environmental standards and have permits if they want to deal with undepolluted ELVs;
- certain recovery and recycling targets are met by 1 January 2006 and 1 January 2015;
- by 2007, producers pay 'all or a significant part' of the costs of treating negative or nil value ELVs at treatment facilities.

Around 2 million vehicles reach the end of their life in the UK each year. Currently, between 74-80% of the weight of a typical ELV is re-used or recycled. Only Rolls Royce has fewer vehicles scrapped than Lotus in terms of percentage of vehicles still on the road compared to vehicles built.

A key consideration in the future will be how the implementation of the ELV directive affects material choice. In the list of selection factors given previously cost was identified as a major criteria. Currently, cost either refers to part cost, BOM cost (if part of an assembly), tooling investment, or combinations of these, usually expressed as a life time cost. However, the fact that producers will pay treatment costs of some ELV's from 2007 will have additional impact. If a particular material is difficult to treat (recycle) or emits some noxious substance during incineration (recovery) or is difficult to dis-assemble (reuse) then this will have an adverse economic effect. Producers must begin to include this additional aspect in the cost calculation i.e. the cheapest material to produce the part may not be the most economical technology in the long run.

Again, appropriate material selection will be key to minimising the risk of large ELV treatment costs to the producer.

Key Business Driver: Passenger Safety (NCAP)

Established in spring 1997, Euro NCAP provides the public with independent, realistic and accurate information about the safety performance of individual car models.

By law, all new car models must pass certain safety tests before they are sold. Manufacturers voluntarily carry out additional testing to cater for accidents not covered by these legal requirements. New car designs are becoming much safer largely as a direct result of Euro NCAP, but manufacturers do still have a choice when deciding on the additional safety features they can incorporate in their cars.

Euro NCAP's tests have been developed to cover as many types of crash as possible, but they do not represent every type of accident. Instead, the tests concentrate on those that are most likely to result in serious and life-threatening injury.

> *There is no "pass" or "fail" in Euro NCA tests; the star ratings and scores show how well cars perform in the tests and inspections against a pre-set standard.*

There is no 'pass' or 'fail' in Euro NCAP tests; the star ratings and scores show how well cars perform in the tests and inspections against a pre-set standard. The cars are inspected after the test, allowing Euro NCAP's ratings to take account of how well the car would protect people of different sizes.

All cars undergo front- and side-impact testing, which includes:

- 64kph (40mph) front impact test to assess car's performance in severe accidentt
- 50kph (30mph) side impact test
- 29kph (18 mph) optional pole impact test to driver's head
- 40kph (25mph) child and adult pedestrian impact tests

Each model is given an overall rating of up to five stars Greater public awareness of the potential consequences of road accidents, combined with the design and engineering skills of the car industry, will significantly reduce the number of deaths and serious injuries on our roads. Materials technologies in terms of structures and compliant 'surfaces' will play a significant role as OEM's pursue the five star ratings.

Key Business Driver: Emissions Legislation

Global warming countermeasures are demanding reduction of CO2 to be achieved through burning less fuel. The Kyoto protocol requires dramatic improvements in fuel economy and European OEMs have made voluntary commitments to achieve corporate fleet average CO2 of 140g/km in 2008 and stretch targets of 120g/km in 2012.

Powertrain strategy in terms of addressing these targets has been described in previous editions of this newsletter. Vehicle engineering has three options available to make a contribution all based around reducing the mass of the car.

The first of these is to downsize the car. The product positioning OEM's undertake with their models, however, makes this an unrealistic proposition – there is little scope to influence marques to this extent.

The second option is to make more efficient use of the materials used. The use of CAE techniques to optimise materials application, however, is standard within the automotive industry and the scope, therefore, of significantly reducing vehicle mass further will be limited.

The final option is to use alternative materials such as aluminium, magnesium, titanium, and composite structures. This option has been discussed within this article.

In Conclusion

The automotive industry faces significant challenges in terms of legislative and product targets. The Materials Engineering department at Lotus continues to play a significant role in the application and development of Metallic Materials technologies and Joining Systems which can help to address many of these issues.

This ability has been recognised by OEM's. The department is increasingly being asked to consider applications of innovative technologies where conventional pressed steel is the norm.

The first step to convince OEM's that quality levels can be affordably maintained with the new technologies is well underway. Our Materials Engineers are continuing to support sales activities on a wide range of initiatives.

The real challenge to maintain the momentum, however, will be to provide solutions for existing OEM infrastructures and to shift the mindsets of their engineers. As the message about new materials technologies and their benefits continues to filter through the Materials Engineering team believe that significant new revenue streams will continue to be realised.

Jason Rowe - Chief Engineer - Materials and Process Technologies.

Materials, Opportunities and Weight

In 1980, more than 64,000 people were killed on Europe's roads and more than 1.8 million injured.

By 2000 the number killed had fallen to 40,890. The number of people injured had dropped to 1.77 million.

But while the European toll declines, globally the number of casualties could increase as more countries become motorised.

With 1.2 million deaths and 35 million road injuries a year worldwide, Dr Jeffrey Runge, administrator of the United States National Highway Traffic Safety Administration (NHTSA), says it is a "health problem of incomprehensible size."

Perhaps the best way to ensure safety is by regulation and to promote a culture where road users obey the law – for example wearing seat belts, not drinking and driving, keeping to speed limits, says Dr Runge.

Other than that safety is in the hands of automakers and governments and here developing countries have the chance to benefit from others' mistakes. It is important to note that the number of European road casualties had fallen by 2000 despite a trebling in the number of vehicles on Europe's roads.

In the US or Western Europe in the late 1940s and early 50s vehicles – and, for that matter, roads – had not been built with safety in mind.

Dr Runge says: "We've moved beyond that and we know what the policies are that have led to a drastic decline in motor vehicles' crash fatality rates.

"With developing countries and those countries that are becoming more heavily motorised now there's a lot of low lying fruit and they need not repeat the mistakes that we made 40 or 50 years ago.

"There is an opportunity now to speed up that evolution by adopting practices that we know work: vehicle safety regulation; use of safety belts; sober driving; speed control and enforcement; public information and education; engineering of safer roads."

But safety – and fuel efficiency - can also be improved by using lighter materials in auto building. Lightweight, strong materials solve the dilemma of cars getting ever heavier and therefore less fuel efficient as more and more equipment is added. The steel and aluminium industries are rising to the challenge and developing and promoting improvements in their products and processes.

Through the International Iron and Steel Institute (IISI) the steel industry has been supporting a range of projects to investigate and promote the use of high strength steels in automotive applications. The ULSAB AVC being the latest in a series of studies to exploit the application of new grades of steels to create safe, affordable and environmentally responsible vehicles.

The Aluminium industry has made significant inroads into the auto industry as demonstrated by vehicles such as the aluminium intensive Audi A8, Audi A2 and Jaguar XJ.

Utilising advanced computer simulation techniques automakers are able to explore the potential of these and other materials and select the most efficient and safe solution. These techniques coupled with rigorous test and development programmes enable the automaker to optimise their solutions to produce high performance products with low mass. A vehicle with lower mass uses less fuel, which in turn will produce fewer CO_2 emissions during its life. Estimates from car manufacturers and others range from 5-10% of fuel economy savings per 10% weight reduction for today's average vehicles.

The Aluminium Association estimates that "over the average lifetime of a vehicle, every pound of aluminium that replaces two pounds of steel can save 20 pounds of CO_2 from being emitted".

Improvement in vehicle operation represents the largest opportunity to minimise the greenhouse gas implications of automotive and other transportation products.

Modelling was therefore conducted to quantify the potential net greenhouse emissions savings associated with the increase in the use of aluminium in today's automobiles and light trucks.

These calculations were based on the cumulative aluminium product results described earlier and automotive manufacturer's estimates of fuel savings. Relative to traditional materials, the results of this modelling indicate the potential to save over 20 metric tonnes of CO_2 equivalents for each tonne of additional automotive aluminium products from enhanced vehicle fuel efficiency, over the vehicle's lifetime.

The aluminium industry is working closely with the automobile manufacturers to enable the easier dismantling of aluminium components from cars in order to improve the recovery of aluminium. Recycling rates for transport applications range from 60-90 per cent in various countries. In 1997 over 4.4 million tonnes of scrap were used in the transport sector and the use of aluminium in automobiles is increasing year upon year.

Today 11.6 million tonnes, close to 40% of the global demand for aluminium in

all markets is based on recycled metal from process scrap and scrap from old products. The increasing use of recycled metal saves on both energy and mineral resources needed for primary production. The recycling of aluminium requires only 5% of the energy to produce secondary metal as compared to primary metal and generates only 5% of the green-house gas emissions.

Magnesium is another key lightweight material and is the lightest of all the commonly used metals. It is one of the most abundant elements in the earth's surface, amounting to about 2.5 % of its composition.

Most pure metals, including magnesium, are too soft for structural use. However strength properties comparable to those of many aluminium alloys are obtained by alloying magnesium with other metals, and, in some cases, by heat treating or working.

Magnesium is also used in desulphurization with other metals, specifically steel. Sulphur has a deleterious effect on the properties of steel, and the increasing demands of the market have forced the steel industry to provide products with lower sulphur content.

Magnesium is light, abundant and recyclable. It can be machined faster and has the best strength-to-weight ratio of any of the commonly used structural metals. It has excellent dimensional stability and is highly impact and dent resistant.

Magnesium has excellent damping capacity and low inertia which makes it a good choice for parts which undergo frequent and sudden high-speed changes in the direction of motion. The new high purity alloys have corrosion resistance better than carbon, steel and some aluminium alloys.

Relatively small additions of magnesium to aluminium will improve its strength and corrosion resistance.

One of the fastest growing structural markets for magnesium is die castings, particularly since the introduction of the corrosion resistant high purity alloys in the early 1980's. Typical of the numerous automotive die castings are cylinder head covers, clutch housings, steering columns, wheels, instrument panels and valve covers.

Why use magnesium for structural parts? The primary reason for selecting magnesium is superior weight-to-strength ratio. Another common reason is its machinability. Other benefits include:

- Dimensionally stable
- Welds easily
- Excellent damping capacity
- Impact and dent resistant
- Corrosion resistant

Carbon fibre is the holy grail of the automotive industry but is too expensive as yet to be used except in highly specialised areas such as F1 racing.

Despite the costs, carmakers have refused to let the idea of a carbon fibre car go away and the industry has just completed a four-year study into its potential.

In 1990, carbon fibre cost around €150 per kilo but this has now been reduced to around €15 per kilo, according to Renault, one of three car makers in the project (Volkswagen and Volvo are the others).

The TECABS (Technologies For Carbon Fibre Reinforced Modular Automotive Body Structures) project is a leading EU project on advanced composite materials for the automotive industry.

With the completion of the manufacturing and testing of a full-scale RTM-produced carbon fibre floorpan with an estimated 50% weight and 70% part count reduction over functionally equivalent steel structures, the TECABS project has successfully validated its material, manufacturing, simulation and design technologies for a composite body-in-white concept within the constraints of an existing A00 type car.

The technologies used in the prototype floorpan - the largest structural automotive part of its kind - allow for a production scenario of 50 units/day, one order of magnitude higher than currently feasible for long-fibre carbon composite structures in cars.

Though not yet ready for application in full-scale production of mass produced cars, the results generated by the TECABS project represent an important step towards wider use of structural composites in the automotive industry.

And then there are polymers. Following a strong period of growth throughout the 1990s, the share of plastics and composites in the composition of cars has remained at around 15%. But, because cars have become heavier, the actual amount of plastics has continued to increase.

Historically, most polymers were used in the cabin, around 50% of the total in a typical car, and under the bonnet. Almost all air intake manifolds on Renault engines, for example, are made of glass-fibre reinforced polyamide, a solution that saves between 20% and 30% of both weight and cost when compared to one involving metal.

With Euro NCAP, which researches car safety, set to reveal the full results of its Phase 15 testing at Real Madrid's Bernabeu Stadium, on November 25th, it is important to consider that it can sometimes be dangerous for drivers to feel too safe.

With cars safer, quieter, more comfortable than ever, some drivers feel so secure they are tempted to travel faster and take more risks.

By Anthony Lewis & Chris Wright

Lotus Vehicle Safety Integration Engineering

The Lotus Engineering vehicle safety group takes a holistic approach to vehicle safety, starting at the front bumper and ending at the rear and including every aspect in between. This allows the company to meet the needs of today's market as well as being ready to meet the ever more stringent demands of new legislation like the forthcoming European Pedestrian Safety directive (2003/102/EC) and revisions to Federal occupant protection legislation. In fact looking forward is essential as current programmes need to reflect the requirements of ever changing legislation and be able to meet these demands by looking many years into the future. Lotus has its own Type Approval group responsible for monitoring worldwide demands for all future programmes and is well placed to be aware of and ensure that future products comply with these ever more demanding requirements.

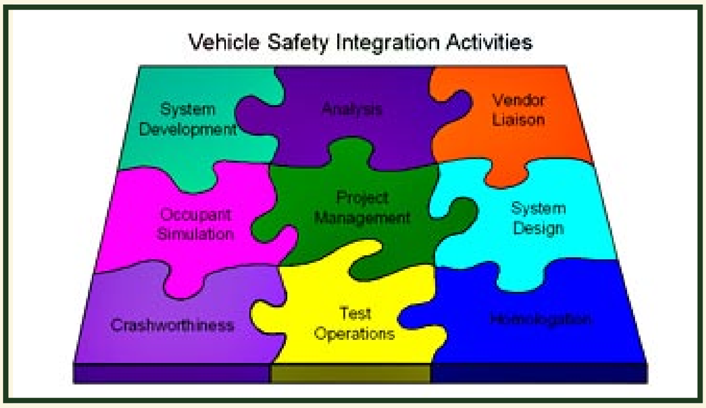


Fig 1: Integration

Lotus Engineering is proud of its ability to provide both traditional and unique solutions to these demands. Traditional solutions involve continual development of steel bodied cars and integrating carry over safety systems to provide competitive crash performance. Lotus also has the ability to develop unique solutions by using its ever increasing knowledge of aluminium and composite crash structures.

In providing these solutions, Lotus utilises third parties' whole vehicle crash facilities and ensures that its engineering teams are fully involved to maximise development and learning. More importantly, Lotus has developed its own in house test facilities to support component and material testing and allow development of its CAE capability. Lotus considers it leads the world in the development of composite materials and bonded aluminium joint solutions for vehicle application.

Crash Structures

Lotus Engineering has design, development and manufacturing capabilities to enable the production of modular composite crash structures which provide very effective and mass efficient energy absorption capability. The use of composites and composite crash structures in both its own and and client vehicles forms a key part of the capability provided by Lotus Engineering. These composite crash structures offer the benefits of high levels of tunability and low tooling cost for low volume production. They are lightweight and offer up to ten times higher specific energy absorption (30-50kJ/kg v 3-6kJ/kg for steel). These composite solutions also maximise the use of available crush length as they offer energy absorption by disintegration and with minimal residual crushed material.

A good example of this is the Aston Martin Vanquish crash structure and tunnel. One of the key programme objectives was to implement innovative technological solutions to achieve world-wide crash worthiness targets with a low weight and low investment structure. The vehicle package demands were also key, due to the need to package the normally aspirated V12 engine and the fact that the vehicle dimensions had already been set by a show car model.

During the programmes concept stages it was decided that the only way to achieve the product demands was through the development of the composite crash structure approach previously used on the Lotus Elise. The Elise solution was less technically demanding due to the extreme lightweight nature of the vehicle. The demands of the Vanquish programme required development of this technology to include a carbon and glass fibre reinforced polyester resin composite crash structure incorporating the front bumper beam. There was also a need for a highly innovative solution for the Federal and Canadian bumper impact regulations where the grille was developed as an energy absorbing structure. This technology has been patented by Lotus.

Fig 2: Crash Structure

The Lotus CAE group provided analysis of the composite crash structure to meet European and Federal crash requirements as well as the customers in house standards and requirements. The rig testing facility at Lotus was vital in developing this knowledge base and confirming the CAE predictions as well as protecting the Intellectual Property Rights of this technology within the group. This capability includes drop testing and linear impactors as well as a free flight head and component crush testing capability in order to validate the CAE models and support development of the materials and technologies employed.

The Vanquish crash structure design was also the first application of Resin Transfer Moulding (RTM) (another Lotus patented technology) for the manufacture of front end crash structures and these crash structures are manufactured by Lotus for Aston Martin.

Fig 3: Drop Test Rig One

The Vanquish was the first Aston Martin vehicle to meet the exacting future Ford worldwide safety requirements with all of the legislative and Ford in-house crash targets achieved or exceeded. Aston Martin is exceptionally proud of the Vanquish crash worthiness, ‘the evident rigidity of the chassis and presence of composite crash structure front and rear, point to strong passive safety’, Autocar August 8th 2001.

The modular design approach has allowed the crash structure to be considered in isolation. Initial design concepts are analysed using CAE correlated to drop tests of test samples tested at Lotus’s in house rig test facilities. Different sections and lay-up samples were tested to optimise the design. Low cost prototype tooling allows complete crash structures to be tested prior to whole vehicle crash tests. Complete crash structures were then tested using trolley testing at off site facilities. These impacts included both offset deformable barrier and rigid 0 degree and 30 degree angled barriers. This rigorous testing provided a very high level of confidence in the performance of the crash structure before whole vehicle barrier tests are conducted. This was vital due to programme timing demands and the extremely high cost of prototypes. Lotus also tested these composite crash structures at elevated and sub-zero temperatures setting a new benchmark for crash performance.

Fig 4: Drop Test Rig Two

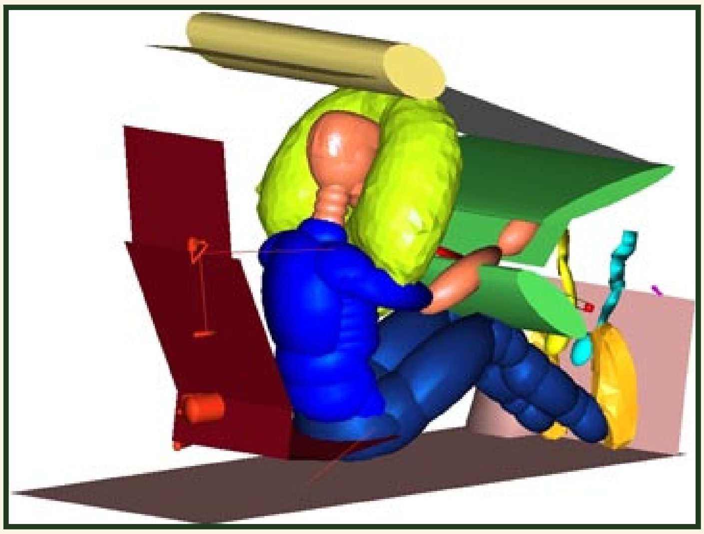
Fig 5: Crush Tube

Lotus also uses this approach of drop testing and trolley testing for the development of steel and aluminium structures and components.

Occupant Restraint System Integration

Due to the ever increasing complexity of restraint systems and the increasingly complicated interactions needed to meet the optimised occupant injury levels Integration of the safety package is no longer just limited to the performance of the airbags and the seat belts.

Fig 6: Occupant Simulation Using MADYMO Software



For front impact the crash pulse obviously has a significant effect and has a major influence on the occupant chest acceleration. The stiffness of the front seat controls the occupants pelvis acceleration both for belted and unbelted. Keeping this pelvic acceleration low is key to reducing femur and lower leg injuries. There are also conflicts. For good EuroNCAP ratings the lower instrument panel needs to be as far away as possible to avoid any unnecessary knee impact. However, for Federal markets, the lower instrument panel is used as a knee bolster to restraint an unbelted occupant. To obtain good occupant kinematics this knee bolster surface needs to be as close to the occupant’s leg as possible. Recent developments to provide a solution for this conflict and meet both requirements are to include knee airbags in the package. For the unbelted driver the column collapse performance is critical. Its mounting stiffness, mounting angle, collapse length and collapse load along with the steering wheel rim stiffness is critical for the driver’s chest displacement injury.

For side impact the structural performance, both rate, and level of intrusion and occupant interaction with the interior of the vehicle are critical in achieving low chest and abdomen injuries. Package of ‘hard’ points within the door structure such as door lock mechanisms and window lift motors need careful consideration. Door trim stiffness and design, style and location of armrests also have an influence on the occupants’ rib and abdominal injuries. Again composite solutions can be included to increase energy absorption, dissipation and increase control of the crash energy. With more and more airbags available it would appear that side impact protection is just a matter of selecting how many airbags are required. However, in some scenarios the presence of an airbag can be detrimental to occupant injury levels and occupant kinematics and more attention must be focused on the structural performance. Again CAE modelling and component testing is vital in achieving optimum performance levels.

These are just a few examples of the issues surrounding Vehicle Safety Integration. To meet these demands the Lotus Vehicle Safety group are involved right from the concept stage. As well as the Vehicle Safety group the programme is also supported by the Type Approval group, CAE group and Rig Testing group right from the concept stage. This approach provides a fully integrated method to finding the correct solutions through development of all aspects and not just a reliance on vendor components and vendors development capability.

It would have been easy for Lotus, as a small volume manufacturer, to transfer its responsibility to vendors and rely on them to supply a working solution. However this would have led to huge compromises in terms of system weight and cost and also reduced our ability to integrate the supplied systems with our advanced structural capabilities. Lotus therefore committed itself to retaining this responsibility and this has led to huge benefits for our own products and those of a number of external customers.

Lotus’ wealth of experience to date includes supporting full occupant protection system integration using either carry-over parts or including new technology and have developed good relationships with a number of Tier 1 restraint system suppliers. It has had experience in tuning component characteristics to improve their performance. These have included design and development for Federal markets of collapsible knee bolster and steering column collapse. Lotus has worked directly with suppliers to develop and specify passenger airbags fold patterns and tethers to meet the requirements for small occupants.

An example of this is the Lotus Elise for the U.S. marketplace. The restraint system and drivers airbag, originally developed by Lotus for the Vauxhall VX220/Opel Speedster, was carried-over to the Elise with the addition of an existing OEM supplied passenger airbag. The tethered passenger airbag door was design and developed internally by Lotus. Even though the restraint system incorporated carry-over components from other platforms the Elise was engineered to meet the current requirements for FMVSS208 for belted and unbelted occupants with no changes to the carry-over components.

Lotus maintains a number of internal research programmes looking at further developments of the composite technologies.

Fig 7: Inside the Federal Elise

Lotus has also supported external research into vehicle and occupant safety. In fact a recent programme has developed a total composite solution for a major OEM which will be used in one of its future new car programmes.

This experience and research capability is now being used to meet the new challenges for the occupant protection systems. Include the IIHS high barrier ‘SUV’ side impact and the proposed changes to FMVSS214 to include a pole side impact for the Federal markets. Both this new crash requirements will involve the installation of head side airbags for the front occupants.

Pedestrian Protection

Lotus has experience in Pedestrian safety requirements for both the EuroNCAP and the forthcoming European Pedestrian Safety directive 2003/102/EC. It has undertaken benchmark activities for external clients and been involved in impact testing to both European directive procedures and EuroNCAP. Currently Lotus is involved in the design and development of new vehicles to meet pedestrian safety requirements. This is being achieved through working with design and CAE in optimising the front-end styling of the pedestrian impact zones and the position and packaging of 'hard' impact items, i.e. wiper spindles, bonnet hinges and latches, lamps and engine components. The Lotus CAE group has all the pedestrian impact tools for the adult and child headforms, upper leg and lower leg and with this capability are working with our Design and Manufacturing Engineering group to optimise the design though design changes and material selection.

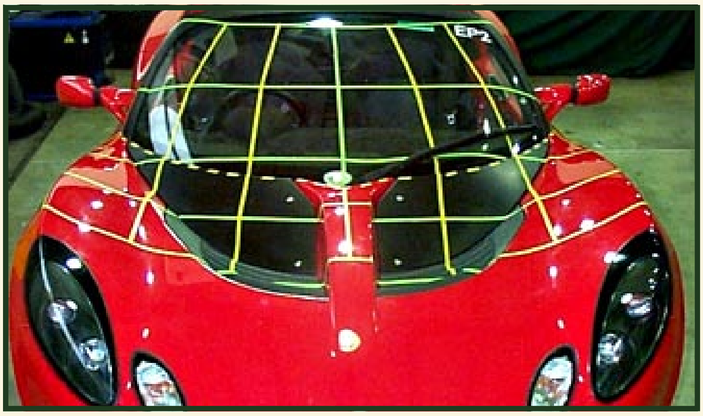


Fig 8: Pedestrian Elise

Fig 9: Lower Leg

In Conclusion

The Lotus Vehicle Safety group takes an integrated approach to vehicle safety with consideration to the vehicle as a whole. This activity is supported by Lotus' in house legislation department, CAE analysis, materials group and rig test facility early in the design concept of a vehicle programme. Lotus is proud of its ability to provide both traditional and unique solutions to vehicle safety including the development of bonded aluminium and composite crash structures, pedestrian safety and occupant protection integration. From this experience Lotus has broadened its knowledge base in the field of composite structural analysis and the manufacture of composite structures using Resin Transfer Moulding (RTM) technology.

By David Tankard – Principal Engineer Vehicle Safety

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