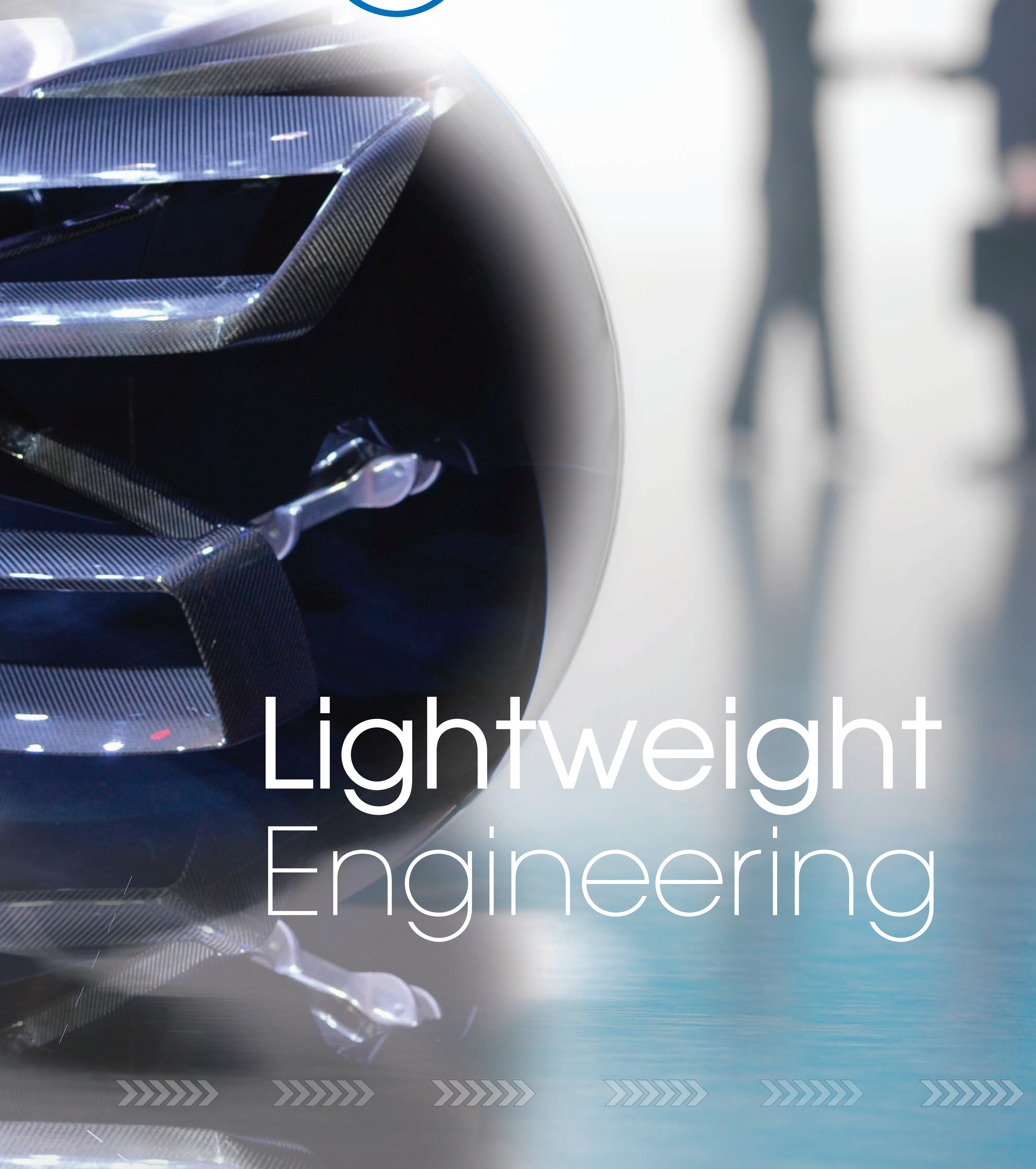
Thatcham Insight

Automotive insight for Members

No.9 April 2013



Lightweight Engineering

Lightweight
ENGINEERING

CAR DESIGN HAS EVOLVED GRADUALLY SINCE THE ADVENT OF THE FIRST MOTOR CARS

Customer demands are driving manufacturers toward greater performance, better comfort, and more attractive designs to tempt the car-buying public to part with their cash. Advances in mass production and lean processes have made significant impacts on car design with production needing to be quick and efficient.

Safety requirements have inevitably also driven changes in design, advances in materials with inclusion of stronger steels etc and inclusion of passive and active safety systems. Cars grew, each generation over the past 10 - 15 years becoming subsequently larger and more sophisticated than its predecessor, with more equipment and bigger power-plants for more dynamic performance.

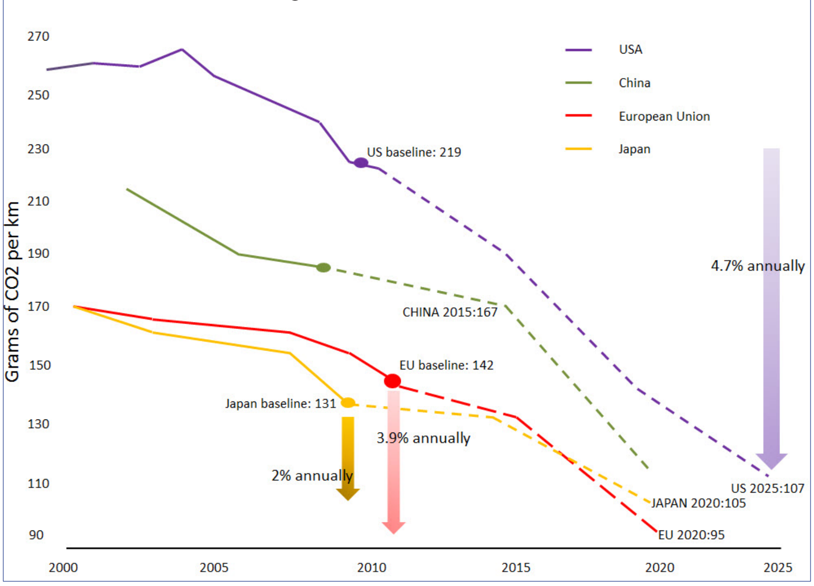
But there has been a step-change and a complete reversal of the trend for vehicles growing heavier and bigger. Demands and legislation for emissions reductions and rising costs of fossil fuels have led to fuel economy being far more of a focus for the manufacturers. The recent introduction of many hybrid and battery electric vehicles is one solution to this.

But the other, perhaps more challenging, solution has been to reduce the mass of the vehicle so that engines can be downsized; less mass = less fuel required to move the occupants on their daily commute.

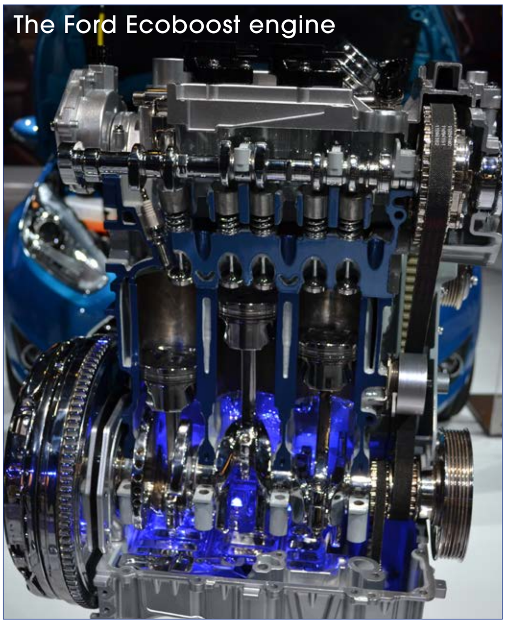
Ford has recently introduced the 3-cylinder 1.0L turbo-charged Ecoboost engine across much of its range, something that would have been unthinkable a few years ago.

Much as we all care for the environment and the future of our planet, in a competitive market we don't want to get less for our money, so the car buying public wants the same levels of performance and the same space inside the car. This places additional pressures on the car designers and engineers.

Emission Reduction Targets for Global Markets



The Ford Ecoboost engine

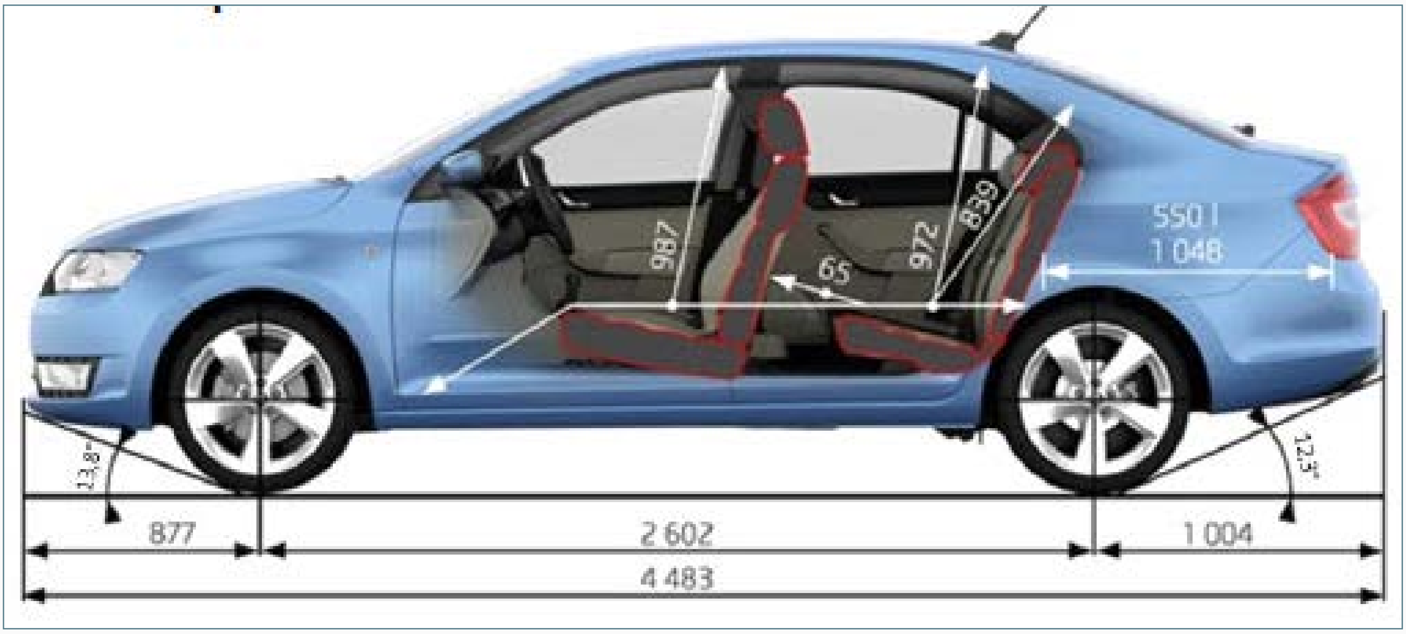


SAME size car
performance
comfort
equipment levels

BUT less weight
smaller engines

how do the manufacturers achieve this?

Well, if you can't make the car body any smaller, the only solution is to use lighter materials, or less of it. Or both. So we have seen the inclusion of High Strength Steels (HSS) and Ultra High Strength Steels (UHSS) increasing generation after generation of each model. We have now passed the point where up to 50% of a vehicle mass could be HSS or UHSS, it is now most likely that far less than 50% of that mass is of mild steels.

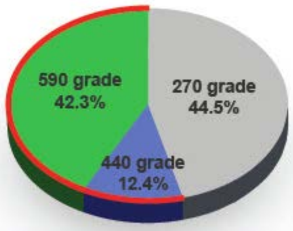


In the case of the Skoda Rapid, a new vehicle to the Skoda range, the vehicle is nearly as big as the larger segment Octavia, but only 5kg heavier than the smaller Fabia.

What is commonly not seen is that in the most recent generations of car models the material gauge has decreased. A structural panel of a nominal tensile strength is replaced with a higher grade material, but thinner and possibly re-shaped. This can and has happened even in mid-life redesign or refresh of a model.

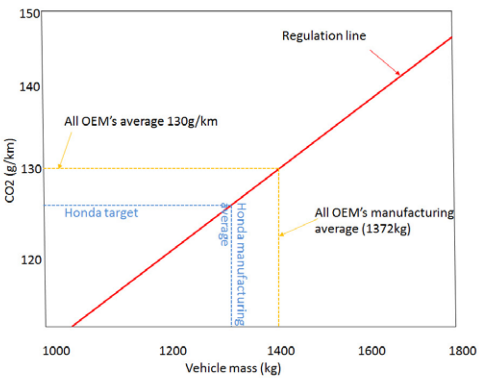
Lightweight
ENGINEERING

Jazz Mk2
Materials Specifications



And this re-engineering is carried through the entire structure, often having a major impact on the final mass of the vehicle, though this can vary. The Honda Jazz Mk2, released in the UK in 2008, made much more use of thinner profile materials than those of its predecessor. Though the weight of the Body In White (BIW) only reduced by 2.8kg, the car was much stiffer than the Mk1, which enables engineers to develop much more dynamic driving characteristics and a safer stronger crash performance.

Honda Weight and Emissions Strategy



The current Audi A3 targeted and achieved an 80kg weight saving over the previous model, whilst still being required to achieve adequate safety ratings expected of a car in this class. This has allowed the vehicle to be marketed with a range of more efficient engines, such as the newly released 1.2TSi that can return up to 57.6mpg, with CO_2 output of 114g/km.

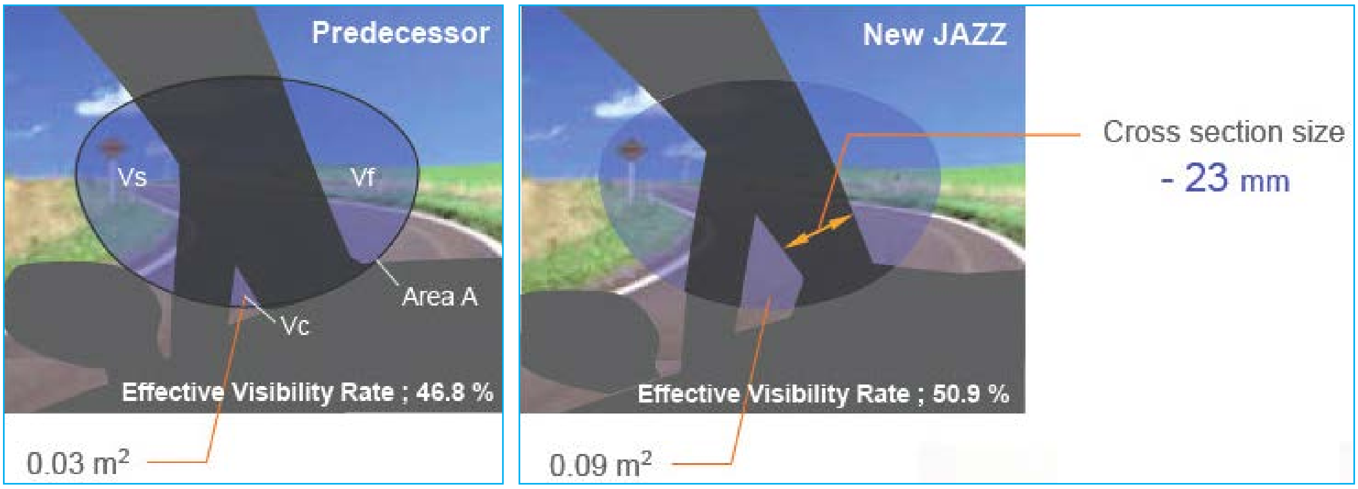
So what are the differences that made the Audi A3 lose so much more mass than the Honda Jazz? To be fair to Honda, the new Audi has been engineered from the ground up on the new VW Group MQB platform to be lighter and more efficient.

HONDA IS A GLOBAL MANUFACTURER WITH 19 PRODUCTION PLANTS BUILDING CARS FOR 160 DIFFERENT MARKETS. TO SOURCE MATERIALS FOR ALL OF THOSE PLANTS IS A HEADACHE, AS IT IS FOR MOST MANUFACTURERS. TO BUILD A CAR SUCH AS THE JAZZ, OR FIT AS IT IS KNOWN IN MOST MARKETS, TO A CONSISTENT STANDARD REQUIRES RELIABLE SUPPLY OF MATERIALS TO A KNOWN STANDARD.

As this is far harder to achieve globally with Ultra High Strength Steels, Honda's solution was to restrict material usage to High Strength Steel in the 590MPas range as it is able to source this material consistently across the globe. Use of harder to obtain higher grade materials such as 780MPas UHSS was kept to a minimum.

So the Honda engineers working toward the Mk2 model used thinner lighter profiles in 590MPa HSS wherever they could. This led to other engineering solutions such as reshaping profiles and more panels overlapping, with bigger joining areas for combined strength and the impact load paths being designed to collaborate.

One example of this was the floor cross-member just behind and protecting the under-seat fuel tank. This previously 3-piece component was replaced with a single piece of higher grade steel and re-profiled significantly to achieve a 95% improvement in stiffness under impact.

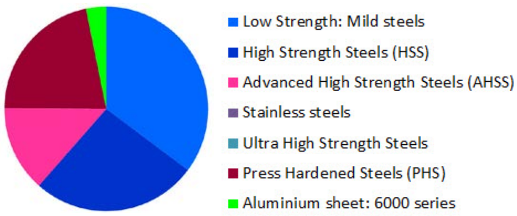


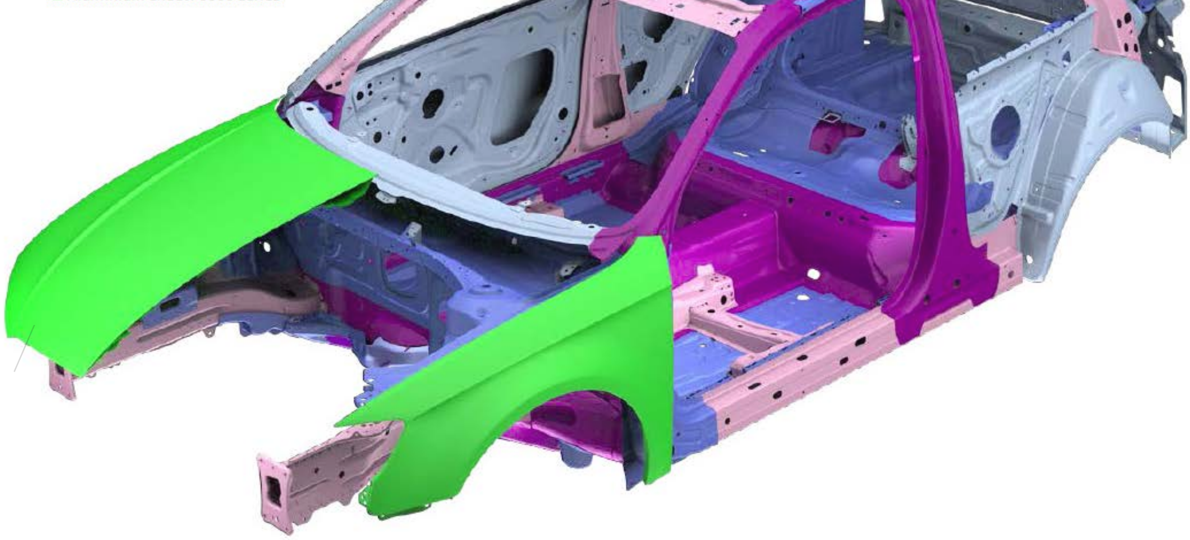
one example of structural gauge reduction

Lightweight
ENGINEERING

Starting with a clean sheet of paper for the A3 has given the Audi engineers (and their VW group colleagues for the Golf Mk7) much more freedom.

VW Group has adopted a philosophy of "right materials in the right place", so rather than the Honda method of engineering a given component to achieve a required performance, the VW/ Audi engineers select the best material for each panel..





So, given this approach it is no surprise that 41% of the Audi A3 comprises UHSS and Press Hardened hot formed material. Good examples of this are in the main transmission tunnel, A and B post areas and floor cross-members.

These structural panels are now formed from press-hardened materials. Whilst as a material these can be expensive and difficult to obtain, the benefits are clear. If you take the Skoda Rapid (and Seat Toledo sister car) as examples, the transmission tunnel was constructed from two components only, predominantly Usibor 1500MPa Press Hardened Steel.

Construction of this same part in less advanced material would have required 7 component parts. But the benefit goes way beyond the 4kg of weight saved by using this material.

The simplified design requires only 14 welds in production, compared with approximately 115 if more conventional but lesser grade materials were used. For manufacturing plants targeted with producing 1200 cars per day the time saving in production is significant. Vehicle manufacturers are only too aware that each individual join is a potential weakness or problem area, so this panel alone has removed 121,200 potential quality problems from the production line each day!

The material gauge hasn't been ignored either by VW/Audi. The press hardened "heel" panel (the floor member under the rear seat bench) has no fewer than 6 thicknesses across its width, even though it is made of one material grade.

The B-post reinforcement of the Audi A3 is another good example of engineering for weight loss. This is a single hot-formed panel that has been partially tempered to soften it in a specific zone for crash impact deformation. The material gauge is thinner than on the outgoing Audi A3, resulting in a weight saving of 1.9kg just for the B-post & Roof side member.

The front external hang on panels of the A3 are made from aluminium; this alone saves more than 12kg over steel components.

Aluminium is an increasingly attractive material for vehicle manufacturers looking to reduce the mass of their vehicles. Aluminium was chosen as the main material by Mercedes and Land Rover for the new SL (R231 model) and the new Range Rover (L405). As a material it has many advantages over steel. It is a strong material, proportionate to its weight, but also it has very predictable deformation behaviour in an impact.

In the case of the new Range Rover (L405) aluminium construction resulted in a massive weight loss of 420kg over the steel bodied previous model. This has enabled a reduction in engine size, giving much improved emissions and performance, with no compromises in structural strength.

This has involved a shift in construction process too, with structural bonding and riveting replacing the welding inherent with conventional car body building. For the first time the production bodyshop is "cold", which makes a much cleaner production environment and the additional bonus to Jaguar Land Rover of an energy and cost saving of 30% over conventional manufacturing. Perhaps as important is that the vehicle body production is reduced from the 270 seconds per body of the aluminium XJ, down to 140 seconds for the Range Rover. Again, this makes an important difference to a production facility planning production of 100,000 units per year.

The L405 Range Rover features cast aluminium suspension strut towers. But it is certainly not the only vehicle to use cast aluminium; this is becoming increasingly common for component areas such as this where structural rigidity is required, with the Mercedes SL BIW being 45% cast aluminium.

By making single cast components the manufacturer can reduce the number of parts required to achieve the same degree of rigidity, with consequential weight saving. The B-post inner for the SL (R231) has integrated 11 other components, and the rear chassis leg assembly has reduced the need for a further 22.

The end result can be huge improvements in body noise and vibration (NVH), as well as much improved rigidity enabling engineers to improve the dynamic performance and agility of the vehicles.

Lightweight
ENGINEERING

In February this year VW confirmed that production of the XL1 SEV (Super Efficient Vehicle) will commence soon at the plant in Osnabrueck, Germany.

This much-heralded two seat, plug-in hybrid (PHEV) is claimed to be capable of 313mpg (the engineering goal being a litre of fuel per 100km). We'll see many cars claiming to be the most efficient in the world, but of more importance is the construction.

In keeping with the engineering strategy of most hybrid/electric vehicles, a large part of achieving efficiency has been through weight reduction of the vehicle, so the hybrid power plant has less mass to move around.

VW has combined a low mass of approximately 795kg (that's less than a VW Up! or a Fiat 500) with exceptional aerodynamics. One look at the XL1 would prevent you from disputing VW's assertion that it is lower than a Porsche Boxster and is clearly a sleek design, but how is it so light-weight?

The body of the XL1 is 230kg (the new Audi A3 is 309kg, itself significantly lighter than its predecessor). This has largely been achieved by using Carbon Fibre (CFRP) and a “minimalist” interior design, where many of the CFRP components are left exposed without trim panel coverings.

This body construction has been largely achieved by the RTM (Resin Transfer Moulding) process, rather than using carbon fibre that has been pre-pregnated with the resins.

VW state that this method results in a CFRP with around 20% of the density of its High Strength Steel equivalent. Nor is that carbon fibre limited to the body, with further use within the anti-roll bars to compliment the significant use of aluminium in the drivetrain.

Of particular relevance to repairers and insurers is the unique and radically different processes employed for the conventional car bodies we see day to day.

McLaren P1

Nor is this the only vehicle of its type. The BMW i3 is due very soon, with its CFRP occupant cell (known as Life Module) on an aluminium chassis, with a fully electric drive system (albeit with a range-extending generator optional).

New materials for vehicle bodies and entirely new construction techniques are no longer just the preserve of high-performance vehicles such as McLaren or Pagani. Volume manufacturers are reaching the limitation of High Strength Steels and further progress in car engineering will involve more composites, re-cycled materials and significantly different joining and construction. Both Ford and General Motors (Vauxhall) are investigating and engineering solutions for CFRP in volume production models.

These steps taken in design and engineering are not considered lightly. Many manufacturers state that their production management are intrinsically involved in vehicle design and development as these changes in engineering need to be carefully considered for production.

We have looked at many cases where reduction in component count and welding time has increased production speed, but these improvements cannot be viewed in isolation as this could merely move a potential production bottleneck further down the assembly line. So production planners, and management, need to be involved to plan for possible consequential changes, such as additional welding and assembly stations at other parts of the process so as not to lose the overall build time benefits gained.

Land Rover developed the L405 Range Rover to efficiently make use of recycled aluminium in construction, but as yet there is insufficient recycled material available within the UK. There is also a short production window with aluminium as the material properties change with age, so material control, storage and handling needs to be robust.

The inclusion of aluminium and composite materials into the process brings many other challenges. Steel and aluminium combined in production creates a more complex requirement for scrap material removal and segregation and CFRP does not suit a conventional car body paint process.

The manufacturer also needs to consider access requirements for different joining techniques and power and consumable supplies to each station. The Solihull production line for the L405 Range Rover utilises no less than 17 types of rivets, 30 types of rivet dies, resulting in 95 combinations of rivet/die, with up to 7 combinations per rivet tool gun.

But more significantly, as with BMW and VW with their i3 and XL1 models respectively, are the major and potentially radical changes to the production process. Certainly with an increase in aluminium and CFRP inclusion these could have an impact on subsequent repair and repair costs.

Thatcham continues to work with the manufacturers and to conduct our own research into repairability and replacement of composites and this new generation of car body is being closely watched and will be researched. Thatcham is ensuring we are ready and today's repairer needs to be budgeting and planning for the right tools, materials and the right training.

This will include ensuring the correct materials are used in the repair as there are many composite fabrics and tape specifications, that the resins used are correct, and that correct processes for laying-up of composite materials and autoclave procedures are understood and adhered to. At present each different manufacturer using composites has their own standard and this could create much confusion and uncertainty for the repairer, and for the customer, and ultimately the insurer who is managing and paying for the repair process.

Many hobbyists tinker with carbon fibre as they have with glass fibre but it should be remembered that these are car bodies with the same Euro NCAP crash performance expectations as a high strength steel body.

But lightweight engineering is not solely the preserve of the body engineer. As we have discussed already, vehicle weight also crept up as a result of customer demands for comfort, infotainment and other fitments. So it is only fair that the burden of weight saving is taken up throughout the design.

There is a natural virtuous circle in that if the body weight is reduced and smaller power-plants are fitted, lighter steering and suspension components etc can be used.

A CLASSIC EXAMPLE IS WITH THE MAZDA SKYACTIV ENGINEERING STRATEGY WHERE EACH ASPECT OF WEIGHT REDUCTION (BODY, ENGINE, SUSPENSION) IS REFLECTED ELSEWHERE.

In the case of the Audi A3 weight has been reduced in many areas: the wiring harness being optimized, the engine exhaust manifold integrated into the cylinder head, thinner walls on the engine crank case and alternative materials used for body components, such as the wheel arch liners.

These are just small steps and the vehicle manufacturers and their suppliers are working collaboratively on many new projects.

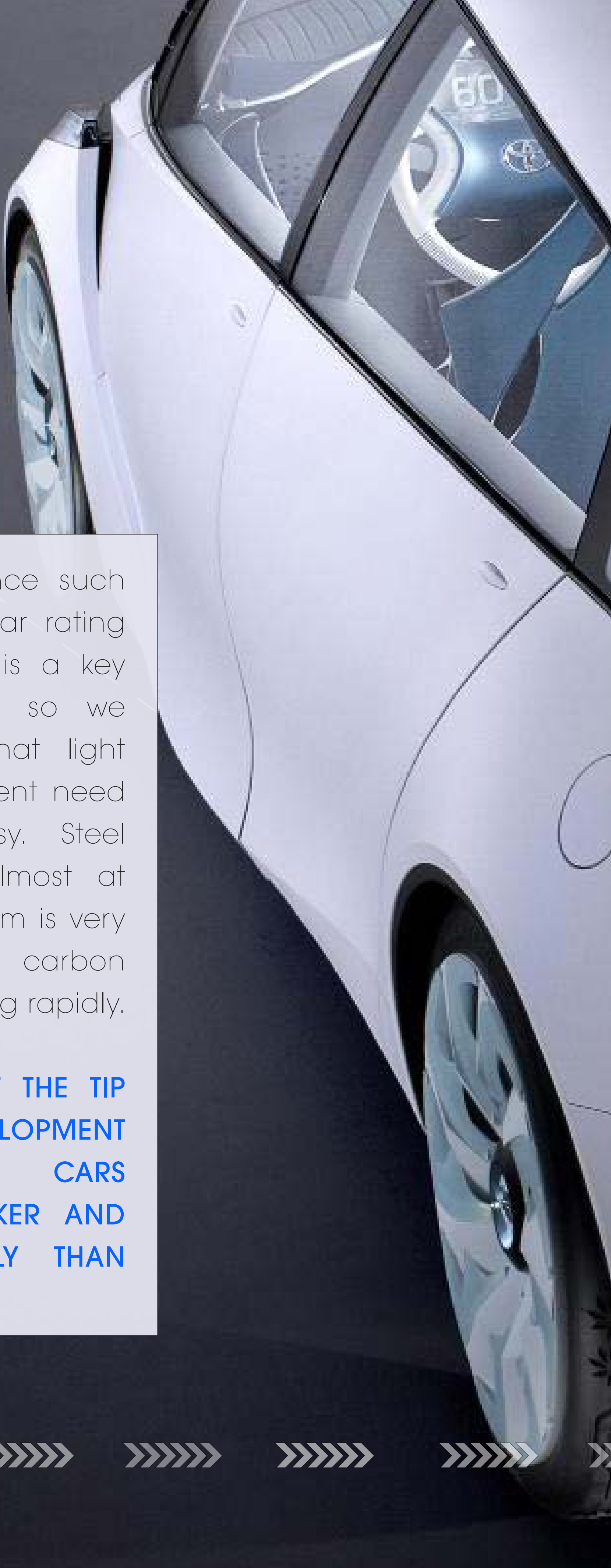
Already carbon fibre can be used for floor panel sections and boot floors etc, but is not suitable for energy absorbing front body structures. Carbon Fibre has huge strength for its low weight, but does not deform like a steel or aluminium crash structure would.

Mazda is looking at ambitious weight saving goals for the replacement for the iconic MX5. The current vehicle has a kerb weight of 1075kg, with the successor targeted as 800kg. Already it has been intimated that it may be powered by a 1.3 litre turbo-charged engine (the current model being 1.8 or 2.0), but amongst the potential weight reducing solutions suggested are boron steel door speakers, possible exclusion of a glove-box and even the owner's manual on a USB stick rather than a printed book. Whilst these seem quite fanciful and maybe even petty, they show that the manufacturers are looking at "whole vehicle" for lightweight design.

Within a few years we may start to see the thin seats seen so often in concept cars at motor shows. These utilise different material structures to the traditional foams, and are compatible with standard current seat frames. Two of the vehicles already mentioned, the Mercedes SL and Range Rover, both include speaker sub-woofers integrated into the aluminium body structure.

Smart is another manufacturer not afraid to be innovative with its city cars. It has already shown model concepts with one-piece door panels with door handles integrated and latch mechanism working off the body. And panels can be moulded in plastics, and even pre-coloured so that painting is not required.

Lightweight
ENGINEERING



Safety performance such as Euro NCAP star rating is still vital and is a key marketing point, so we can be sure that light weight and efficient need not mean flimsy. Steel technology is almost at its limits, aluminium is very advanced, and carbon fibre use is growing rapidly.

BUT THIS IS JUST THE TIP OF THE DEVELOPMENT ICEBERG WITH CARS EVOLVING QUICKER AND MORE RADICALLY THAN EVER BEFORE.

Future concept vehicles are clearly showing that manufacturers are doing further work to meet the challenges. The FT-Bh shown by Toyota at last year's Geneva motor-show was clearly an exercise in engineering to reduce mass. This car will probably provide much of the basis for a future Yaris model and by that time, 2017, the kerb weight of new vehicles will be markedly reduced from what they are today. So the FT-Bh, with its 786kg mass, just 2/3 of that of the current Yaris, won't seem such an unrealistic stretch.

So, much of this methodology and technology is very much here and now. Some of it is in development and may or may not reach production. But what is very clear and open is that most, if not all, the manufacturers have a long term strategy for vehicle design evolution as well as sales and market share. Reduction of emissions and environmental impact will all be part of that strategy and the engineers will be clearly targeted model by model with further improvements in design.

Thatcham. INSight

Automotive insight for Members

Colthrop Way, Thatcham
Berkshire RG19 4NR

t: +44 (0)1635 868855
f: +44 (0)1635 871346
w: www.thatcham.org

Thatcham Automotive Academy
Daytona Drive, Thatcham
Berkshire RG19 4ZD

t: +44 (0)1635 293174
f: +44 (0)1635 868863
w: www.thatcham.org

Thatcham (Thailand) Co., Ltd
128/208, 19th Floor Unit G,
Phayathai Plaza Building,
Phayathai Road,
Thung Phayathai,
Ratchathewi,
Bangkok 10400
Thailand

t: +66 (0) 2 612 0359
w: www.thatcham.org/thailand

Member Companies

Admiral Insurance Co. Ltd
Ageas Insurance LTD
Allianz Insurance PLC
Amlin UK
Ansvar Insurance Co.
Aviva PLC
Axa Insurance (UK) PLC
Brit Insurance Ltd
Chaucer Insurance
Churchill Insurance Co. Ltd
Co-Operative Insurance Society Ltd
Covéa Insurance
Direct Line Insurance PLC
Ecclesiastical Insurance Group
Equity Red Star Motor Policies
Esure Insurance Ltd
Groupama Insurance Co. Ltd
Highway Insurance Co. Ltd
Insurance Corp of Channel Islands Ltd
Jubilee Motor Policies at Lloyd's
KGM Underwriting Agencies Ltd
LV=
Newline Group
Novae Insurance Co. Ltd
QBE Insurance Co. (UK) Ltd
RSA PLC
Tesco Underwriting Ltd
The NFU Mutual Insurance Society Ltd
UK Insurance Ltd
Zurich Insurance Co.

THATCHAM IS A NOT-FOR-PROFIT ORGANISATION

EXPERTS IN SAFETY, SECURITY AND CRASH REPAIR