The International Journal of Motorsport Technology

Racecar engineering™

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PETROL ENGINES FIGHT BACK
How Aston Martin developed its LMP1 V12 for Le Mans

TOURING CAR RETHINK
Alan Gow on the BTCC's new technical regulations

LOTUS ACTIVE SUSPENSION
The story behind an innovative era in Formula 1

F1 GOES OFF ROAD
HOW HIGH-END TECHNOLOGY WON DAKAR

Regress to progress


Penske's new approach to racecar damping revealed

Green power
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'Anti' effects
Danny Nowlan clarifies his views on anti dive and anti squat

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There's something of an Aston Martin theme to this month's issue – and deservedly so. After the evocative sight of that trio of Gulf-liveried, petrol-engined coupés carrying the fight to the diesels at Le Mans this year, the time seemed right to investigate how Aston Martin Racing went about developing its road going V12 into a fuel-efficient, front-running, Prototype power unit.

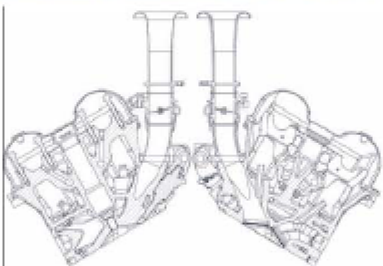
It's a fascinating story, made all the more timely by the fact that it has recently been announced that the factory LMP1 coupés will compete in the final two rounds of this year's Le Mans Series, at the Nürburgring and Silverstone, as well as at Petit Le Mans. Staying with Aston Martin, we also take a close look this month at the evolution of the Vantage-based GT2 version of the car.

In addition, we have our usual informative array of features this month, including the lead story, detailing how Volkswagen Motorsport adopted a high-tech approach to taking on – and winning – the famous Dakar Raid that would have done a top Formula 1 team proud.

We also look at Penske Racing Shocks' innovative regressive damper and provide an historical perspective on how Team Lotus went about developing active suspension during one of the most exciting periods in modern Formula 1.

Add to that an in-depth interview with Alan Gow and Peter Riches on the New Generation Touring Car regulations, plus a first-hand report on driving the University of Hertfordshire's groundbreaking, all-electric Formula Student car, and there should be something for everyone with an interest in motorsport engineering in this month's magazine.

EDITOR
Graham Jones



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FORMULA 1

Peace in our time in F1

Teams and governing body unite on a way forward for the next three years

A NEW UNIFIED Concorde Agreement has been signed, marking an end to any plans for a breakaway Formula 1 series, a threat that has dogged the sport for much of the season.

The new deal will commit the teams to F1 until 2012 and was signed by all 12 squads intending to be involved in next year's championship. The only team not to sign was BMW-Sauber, following the company's withdrawal from the sport (see below). FIA president Max Mosley and rights holder Bernie Ecclestone also signed, bringing to an end an extended period of political unrest within the sport.

In signing the Agreement the teams have committed to reduce budgets, aiming for a level of expenditure close to that of the early 1990s, while the F1 regulations are now set to remain the same for 2010 as they are this year. The one notable exception to this is a ban on refuelling during races.

The governing body said: 'The FIA looks forward to a period of stability and prosperity in the FIA Formula 1 World Championship,' while a FOTA statement said: 'FOTA's attention will now turn to other issues we believe to be in the long-term interests of F1: racing at the best tracks, in front of the biggest audiences and expanding F1's reach.'

BMW to quit Formula 1

It's bye bye from the Bavarians in F1, but hello BMW in DTM

FORMULA 1 HAS lost its second major manufacturer team in nine months with the announcement that BMW is to pull out of the sport at the end of this season.

The Munich firm's announcement comes on the back of poor trading figures and, perhaps more tellingly, a disastrous season on track in a year in which its stated aim was to win the World Championship. BMW-Sauber is currently (pre-Valencia) eighth in the Constructors' Championship on eight points, ahead of only Toro Rosso and Force India, a year after claiming its first win and actually leading the championship at one point.

BMW's withdrawal comes just nine months after Honda quit the sport, and the firm cited a new focus on sustainability and the environment as a reason for the pull-out.

Dr Norbert Reithofer, chairman of the board at BMW AG, said: 'Premium will increasingly be defined in terms of sustainability and environmental compatibility. This is an area in which we want to remain in the lead. We are continually reviewing all projects and initiatives to check them for future viability and sustainability. As such, our F1 campaign is less a key promoter for us.'

There has been no word on redundancies at the team's Hinwil, Switzerland and Munich, Germany bases – the latter responsible for the drivetrain – while a move by Peter Sauber to re-buy the team has fallen through. BMW-Sauber's position in the F1 championship is now up for grabs and those teams that failed to scoop one of the three extra slots available from 2010 earlier this year have been invited to reapply for the now vacant position on the grid.

BMW is to remain in other forms of motorsport and rumours have surfaced that it's to join the DTM to take on arch rivals Audi and Mercedes.

SEEN INDY CAR AERO MODS


Changes to the aerodynamics at the rear of the Indy Car Dallaras, plus a push-to-pass system, seem to have done the trick when it comes to spicing up the oval race action in the series. The recent Kentucky race featured plenty of overtaking, much side-by-side action and a winning margin of just 0.0162 seconds. Job done.

DRIVETRAIN

Stroke of genius

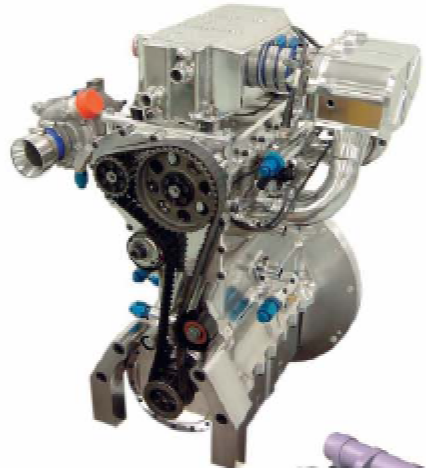
FAMED MOTORSPORT ENGINE builder Ilmor has unveiled an all-new, five-stroke engine, which could point the way to the future for fuel efficient engines on the road and the track.

The engine prototype, currently in dyno testing, aims to demonstrate the benefits of the five-stroke cycle, as invented by Gerhard Schmitz, and Ilmor says the engine will deliver the fuel economy of a diesel, but without the emissions problems often associated with such engines.

The five-stroke concept engine uses two high-pressure fired cylinders operating on a conventional four-stroke cycle that alternately exhaust into a central low-pressure expansion cylinder, whereupon the burnt gases perform further work. The low-pressure cylinder decouples the expansion and compression processes and enables the optimum expansion ratio to be selected independently of the compression ratio.

The upshot of all this is that the engine runs an overall expansion ratio close to that of a diesel – about 14.5:1. The engine, in its current configuration, is also compact – it's just 700cc, yet it gives 130bhp.

Ilmor is looking for technical partners for the project, specifically an OEM, and while it has not been designed with motorsport in mind, Simon Young, a design engineer at Ilmor, told *Racecar Engineering*: 'Originally it wasn't designed for racing but, with the way the auto industry is going, then probably racing is going to have to reflect that. I wouldn't be surprised if fuel efficiency formulas do pop up in the future, so even though this hasn't been designed with a racing application in mind, there's no reason why it couldn't be used for racing in the future.'




Two conventional high-pressure cylinders, which exhaust into a single low-pressure cylinder, that's the concept of the five-stroke engine

TECH SPEC

ILMOR 5-STROKE

Engine capacity: 700cc (turbocharged)

Peak power: 130bhp at 7000rpm

Peak torque: 166Nm at 5000rpm

Minimum fuel consumption: 226g/kWh

BRIEFLY...BRIEFLY...BR

ALMS CLASS ACTION

The American Le Mans Series (ALMS) is to simplify its class structure for next season, with a single LMP class and a single GT class, plus an extra prototype division for the one-make, ORECA-built Formula Le Mans cars, which will be known as LMP Challenge. The championship will, however, revert back to LMP1 plus LMP2 for its blue riband Sebring 12 Hours and Petit Le Mans events.

VATANEN NAMES TEAM

FIA presidential hopeful Ari Vatanen has announced the key cabinet members who will support his bid. Spaniard Fernando Falco y Fernandez de Cordova has been put forward as his candidate for president of the FIA senate, Bernard Tay, from Singapore, has been nominated as deputy president for mobility, while German Hermann Tonczyk has been proposed as deputy president for motorsport. The election will take place on 23 October.

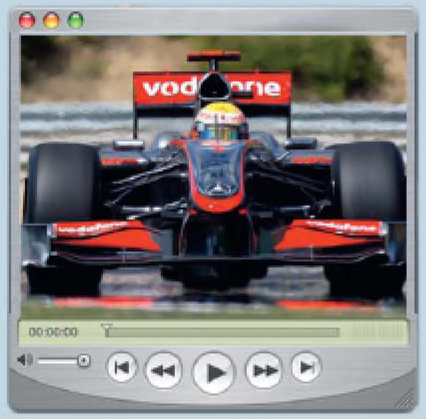
RACING GREEN

The Environmentally Sustainable Motorsport Commission, a new FIA think tank, has written to all FIA rule-making bodies to ask them how they intend to address environmental issues in motorsport. It is urging that they move towards regulations that place more emphasis on efficiency rather than outright performance.

WATCH THIS

How McLaren turned the MP4/24 into a grand prix winner – a four part special documentary

Go to: http://www.racecar-engineering.com/vids



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FORMULA FORD

Honda Jazz up ageing formula

Japanese manufacturer offers an alternative engine to the US Formula Ford series

HONDA HOPES TO re-invigorate the entry-level US single seater racing scene with an all-new Formula 'Ford' 1600 engine.

The engine, which is actually a 1500cc L15A7 unit, usually found in the bay of a Honda Fit (called the Jazz in Europe), has been developed by Honda Performance Development (HPD), based in California, and features fuel injection and a modern ECU. It will be supplied with a kit to make it a bolt-in replacement for the ageing Kent engine and a prototype version has already made its track debut in the back of a Swift DB1 at the US Formula Ford 40th anniversary meeting at Elkhart Lake.

Roger Griffiths, who manages the development division at HPD, told *Racecar Engineering*: 'We realised that the Kent engine that's been used for the last 40 years is getting a bit long in the tooth, is getting impossible to find and is ridiculously expensive. We looked at the range of Honda engines and thought this would be perfect. It's a very simple engine, it produces the right amount of performance, it's physically very similar in size, so we felt it would be an ideal replacement.'

The engine has been developed by HPD, in cooperation with Sandy Shamlian of Quicksilver RacEngines, and every effort has been made to ensure its performance does not exceed that of the Kent, with an HPD-developed intake restrictor plate and appropriately mapped ECU. 'If we overlay power curves, they are identical,' says Griffiths. But he added that if testing reveals the need for additional performance adjustments, changes can be made to the restrictor plate and/or the ECU map.

As for the matter of the Ford name, Griffiths says: 'We have no intention of changing the name, because we're not offering it as a replacement engine, we're offering it as an alternative engine. Of course, the association with another car maker is not great, but there's the history, and that's extremely important.'

The engine is now awaiting SCCA approval for racing in the US, and is to be priced at $12,000 (£7300). We'll bring you more on the new Honda Formula Ford engine in next month's issue.

Honda's alternative to the Kent Formula Ford engine is this 1500cc unit, developed by HPD and Quicksilver RacEngines

CAUGHT!

Rick Ren, the crew chief for the no 33 car driven by Ron Hornaday in the NASCAR Camping World Truck Series, has been fined and placed on probation until the end of the year, after it was found that the mounting points on the axle of the Kevin Harvick Inc Chevrolet were not evenly spaced. The infringement was discovered at the opening day inspection at the Kentucky Speedway event in July.

FINE: $5000 (£3000)

The **Renault F1** team was fined for releasing Fernando Alonso from his pit before his right front wheel was attached at the Hungarian Grand Prix. The team was initially suspended from the following race, the European Grand Prix at Valencia in Spain, but this penalty was reduced to a fine after it appealed.

FINE: $50,000 (£30,500)

NASCAR

Goodyear says it's a 'yes' to wets

NASCAR'S TYRE SUPPLIER has let it be known that it would be able to supply a wet-weather tyre should the organisation ever decide to run road course races in the rain, the announcement coming during the Watkins Glen event, which was postponed until the Monday because of the wet conditions.

Goodyear actually took rain tyres to Watkins Glen for the Nationwide race but they were not used. The second-tier cars did race in the rain at last year's Montreal event – and Greg Stucker, Goodyear's spokesman, said he did not believe the company would have a problem developing a rain tyre for the Cup cars, too: 'There's not that big a difference between the two cars. We're confident we could have a package that would be suitable, if that's what they choose.'

Goodyear has been developing new wet rubber this year, part of a process it started last season, and it tested one version towards the end of 2008. 'We developed a [tread] pattern, modified it for our use, then tested it at our proving ground in San Angelo,' Stucker said. 'We're able to run it where we can wet [the track] down and confirm everything we wanted to see.' Stucker added that last year's race in Canada gave the company some useful data to work with.

But, despite Goodyear's upbeat assessment, NASCAR president Mike Helton went on record at Watkins Glen saying that the organising body has no plans to change its stance on racing in the wet on road courses in the near future.

BOOKS

Racing Colours

Authors: David Venables (Blue/Green);
Karl Ludvigsen (Silver/Red)
Ian Allan Publishing
£24.99 each

RACING COLOURS IS a set of books charting the paths taken by Europe's four big motorsport players: Great Britain; Germany; France and Italy. Based on the traditional national competition colours of British Racing Green, German Racing Silver, French Racing Blue and Italian Racing Red the series provides a great overview of European motorsport, from the first Paris-Rouen race in 1894 through to modern-day F1.

Lavishly illustrated and well researched, the titles highlight the cars, drivers, industrialists and circuits that have formed racing legend. Despite being in the same series, the four books take differing approaches to each nationality, with *Racing Green*, for example, dedicating a chapter to each marque, whilst the other titles adopt a chronological approach.

The motorsport arms race has seen the appearance of some true engineering marvels, including the 1927 Grand Prix Delage (competitive from its inception right through to the 1950s), the phenomenal pre-war Auto Unions and Mercedes and Porsche's dominating Sportscars of the 1970s and '80s, all of which are covered in this series.

Given the vast breadth of subject matter, the books do justice to some of the most impressive cars, drivers and personalities in European motor racing's colourful history.

For more information visit
www.ianallanpublishing.com

SENSORS

ACTIVE SENSORS LAUNCHES NEW MINIATURE LVDT SENSOR

ACTIVE SENSORS HAS launched a miniature, high temperature, LVDT (Linear Variable Differential Transformer) sensor in a 6mm diameter body for mounting in the brake caliper and clutch release systems used in Formula 1 and endurance racing. The LT0600, with a measurement range up to 25mm (1in) is the most compact and accurate high temperature LVDT sensor currently available for competition applications. The design utilises the latest inductive wire 'layered' winding techniques, coupled with the correct coil encapsulation compound, to ensure its survival in severe vibration and temperature (+400degC (750degF)) environments. The sensor is also available with FIA homologated single, duplex or quad in-line signal conditioning electronics.

For more information visit
www.activesensors.com

TOOLS

PELICAN MOBILE TOOL CASE

The 0450 tool case was specifically designed for use by the military as a GMTK (General Mechanic's Tool Kit) but is now being introduced for civilian use. The 0450 mobile tool case combines the flexibility of seven removable drawers, designed to suit a multitude of configurations, with the mobility and benefits of a rugged, watertight protector case. Capable of holding up to 45kg of tools, the 0450 has been tested to meet and exceed 96 demanding military standards, including impact resistance, extreme temperatures and submersion. The top compartment features a removable utility tray and a lid that opens 180 degrees to create a mobile work area, capable of holding up to 23kg. The case also features two automatic pressure equalisation valves that prevent vacuum lock and make the case easy to open at extreme altitudes.

For more information visit
www.pelican.com

ELECTRONICS

BLIND CONNECTOR

THE LE MANS-BASED connector specialist has released a new blind mating plug for quick and easy installation in hard to reach areas of the wiring loom, such as dashboards, car bodywork and adjustable front wings on open wheelers. The 8STA connector has an aluminium alloy casing with a conductive zinc plating. The scoop-proof component is available in a number of sizes and pin configurations.

For more information visit
www.souriau.com

Diesel does Dakar

28 years after winning the second ever Paris-Dakar Rally Raid, VW's victory in 2009 with the Race Touareg 2 was historic in more than one respect

BY SIMON MCBEATH

Dubbed 'the last big adventure', the 'Dakar' makes other forms of endurance racing look like a cakewalk by comparison. There may be occasional longer distance rallies, but there is surely no other regular event that combines the distances, terrain and varied environmental conditions the Dakar throws at competitors. Add to this mix the incredible altitude changes posed by the Andes mountains as the event this year switched to South America (following the terrorism threats that caused its cancellation in Africa in 2008), and it's not hard to see that

TECH SPEC

VW RACE TOUAREG 2

Class: Modified Cross Country Cars Group T1

Chassis: aerospace-spec tubular steel spaceframe

Suspension: double wishbones, twin spring / dampers per wheel, 250mm maximum suspension travel

Engine: 2.5-litre, in-line, five cylinder, longitudinally mounted, twin stage turbocharged diesel with intercoolers, 280bhp, over 600Nm torque, 38mm FIA/ASO air restrictor, Bosch EMS

Transmission: permanent four-wheel drive, Xtrac five-speed sequential gearbox, hydraulic triple plate ceramic clutch, three mechanical differentials with selectable viscous locking

Bodywork: two door carbon fibre body

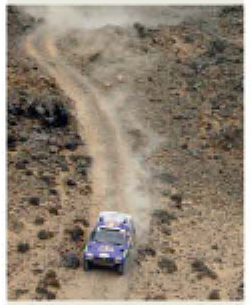
Length/width/height: 4171/1996/1762mm

Track width: 1750mm front and rear

Wheelbase: 2820mm

Minimum weight: 1787.5kg

THE 2009 DAKAR



After direct terrorist threats against competitors led to the organising body, the Amaury Sport Organisation, cancelling the African event in 2008, a new route, and a new continent, was required for this year.

- The new route ran from Buenos Aires, Argentina, as far south as Puerto Madrin, before going north to Mendoza and then across the Andes to Valparaiso in Chile. From there, it went as far north as Copiapo and the Atacama Desert before re-crossing the Andes to Fiambala and from there southeast back to Buenos Aires.
- The race comprised 5652km (3516miles) of special stages over 14 competitive days. Including liaison sections, the total event mileage was 9574km (5955miles).
- To put this into perspective, the competitive distance of the Dakar exceeds that of an entire Formula 1 season, but condensed into two weeks.

The Touareg's engine is a 2.5-litre, twin-stage turbocharged diesel, re-mapped to produce 280bhp/600Nm of torque

The spaceframe chassis is clothed in a carbon composite body, modified for improved aero and better driver visibility

the engineering challenge in simply arriving at the finish is immense. So how did eventual victors VW prepare for this year's challenge? To find out *Racecar Engineering* talked to the engineers in charge.

ENVIRONMENTAL CHALLENGE

VW returned to the Dakar in 2003 with a buggy called Tarek, fitted with a TDi engine, and then again in 2004 with a programme based on the so-called Race Touareg (RT), aimed squarely at developing a diesel vehicle capable of not just winning its T1 (Modified Cross Country Cars) class but of winning overall. It enjoyed increased competitiveness but also what must have been a fair degree of frustration year on year as it got to grips with, but didn't quite master, the demands of the North African desert stages (see sidebar on VW's history in the event). The move to South America in 2009 brought with it even greater challenges, with altitude differences along the route of some 4700m (15416ft), temperatures ranging from freezing to 40degC (104degF), the Atacama Desert (the world's driest place) and the highest dunes on earth to add to the usual sandy and rocky terrain one would normally expect.

So what information or data did the teams have to help their planning? VW Motorsport's technical director, Andreas Lautner: 'There was an agreement to do no investigations for possible routes in order to save money. The final route was published only a few days before the start of the rally and exact information was handed out each evening [during the event]. The only thing we had in advance was information from the organisers with some pictures of the different surfaces and data on the altitudes we had to cross.

The biggest difference compared to Africa was the high altitude, but also the temperatures were a little higher than in earlier Dakar rallies. Furthermore, we expected more water crossings and rain. We analysed the amount of rain in these areas in the last 10 years and this suggested an appreciable risk of rain. As to the terrain and track surfaces themselves, the biggest difference was the 'white sand' – a special kind of really soft sand encountered in the Argentinean summer. And another special matter was the puncture risk caused by cactuses!'

> “developments aimed at achieving performance improvements were detail solutions”

PRE-EVENT PREPARATION

In a nutshell then, the only data with which any objective and specific preparation could be carried out was the altitude and likely temperature range, but at least this gave the engine and aerodynamics departments at VW Motorsport something to sink their teeth into in advance, of which more later. The overall development objective though was very down to earth. Lautner again: 'We primarily focussed on the durability of the Race Touareg 2 and, in collaboration with the quality inspection and control department, we achieved major success. We produced a car of the highest quality standards, which is what we needed in order to win such a tough cross-country rally. For this reason, the other developments aimed at achieving performance improvements were detail solutions, such as a new wishbone for the rear suspension, improved driver visibility and an optimised hydraulics system for the dampers.'

Extensive testing was carried out in August 2008 in Morocco, North Africa, and although performance assessment and development was a part of that, the focus was again primarily on endurance. Extensive component testing was performed over a number of weeks, and key among these was an updated all-terrain tyre from BF Goodrich, which proved to offer better performance on soft sand, as well as improved ruggedness.

With the Dakar route taking in some of the most remote and inhospitable places on earth, satellite navigation and GPS technology is de rigeur. A brace of rally trip meters ensure accurate measurement of stage times and distances

PROVEN POWERTRAIN

RT2's powertrain was already well proven, having taken nine victories and 29 podiums from 29 miscellaneous cross-country event starts since 2004. Natural evolutionary development had occurred along the way of course too, the engine's output having risen to 280bhp with over 600Nm (440lb.ft) of torque. Head of engine development at VW Motorsport, Donatus Wichelhaus, explained the advantages of the 2.5-litre, twin turbo, diesel (TDi)

VW'S RALLY RAID HISTORY

January 1980
The second ever Dakar, VW enters four Iltis vehicles and secures first, fourth and ninth places.

2003
VW returns to the Dakar with a TDi-powered prototype buggy Tarek, achieving first and second places in the 2WD category.

2004
VW enters the Race Touareg for the first time, achieving one stage victory and sixth overall in the event.

2005
VW returns to the podium after a quarter of a century with a third overall. It's the first podium position in the event's history for a diesel-powered vehicle. Four stage victories and four days in the overall lead indicated increasing competitiveness.

2006
Steadily improving, the Race Touareg 2 scores second overall, five stage wins and five days in the overall lead.

2007
Fourth overall is poor reward for 10 stage wins and the first eight days in the lead. First in the diesel class.

2008
Event cancelled due to terrorist threats and political instability in Mauritania.

2009
Event switches to South America. VW achieves first, second and sixth positions overall with Race Touareg 2.

LOGISTICS AND BACK UP

Although anything up to 80 per cent of Dakar entrants are amateurs, often racing on tiny budgets, when the manufacturers go racing, it's a very different matter. Here's how it breaks down:

- VW Motorsport sent 23 vehicles (including four MAN service trucks shipped the previous November), 80 team members and 50 tonnes of spares, tools and equipment to South America.
- The loading list for one MAN service truck runs to 60 A4 pages.
- On every service truck is a toolbox with 27 sets of pliers, 58 spanners and 48 screwdrivers. In addition, every mechanic carries the tools that are necessary for his specific work on a Race Touareg 2.
- Technical director of VW Motorsport, Andreas Lautner: 'The Dakar is the complete opposite of disciplines like Formula 1. Instead of operating in clinically clean conditions, the mechanics have to keep the vehicles in perfect shape even when the cars are extremely dirty. This is an ideal discipline to prove technical competence.'

Front suspension uses twin damper / spring units for safety and to share the immense forces encountered across a wider area. A revised damper hydraulic system was developed in conjunction with technology partner ZF Sachs

unit: 'The engine, which features a two-stage turbocharger system to give improved driveability and an extended torque range, develops very good torque, which has a positive effect, particularly on sandy ground. And due to its lower fuel consumption a diesel-powered vehicle can start a long leg with less fuel in its tank. The weight advantage from this compared to a spark ignition engined vehicle can be as much as 200kg.'

But so seriously was VW taking the challenge of the 2009 Dakar that it imposed upon itself further extensive powertrain testing, completing long runs under rally conditions, as well as different dyno programmes. Wichelhaus: 'Compared to other events, the conditions we encounter differ a lot – we have changing temperature and altitude, dust, water and so on. For this you need special solutions. For example, to prove the car's sealing we used off-road testing, driving through large areas of soft sand or crossing rivers. To simulate the extreme altitude we used special environmental test chambers to adjust the engine to the very different barometric pressures.'

OXYGEN LEVELS

In this way the team was able to simulate the air pressure conditions they were going to encounter in the Andes and evaluate and re-map the engines under load in a '99 per cent simulation of the real-world conditions'. The effect of the high altitude is to place increased demands on the turbocharger, and to try to compensate for the decreased oxygen content the turbo needs to be spun faster to try to prevent losing too much power. But the same output as at sea level cannot be achieved because, to maintain reliability, boost pressure cannot be too high. As Wichelhaus commented:

> "environmental test chambers [were used] to adjust the engine to the different barometric pressures"

'If you adjust the mapping in such a way that the turbocharger does not over rev then a loss of power is to be expected. At the highest altitudes on this event this loss amounts to just over 20 per cent.'

Extreme ruggedness and compliance might sum up the main requirements of the suspension on a Rally Raid vehicle. Compliance, however, is slightly restricted by the maximum 250mm (9.84in) permitted wheel travel although, as Andreas Lautner reasonably pointed out, 'if you could use more wheel travel you would need a lot more effort to get a car reliable in terms of driveshafts, wishbones and bearings.'

Dual spring / damper units per wheel are commonplace in this game, for reasons that seem obvious, but which were succinctly summarised by Lautner: 'One reason is to have a still functional system in case of a broken damper. But the main reason is the huge forces that go into the suspension. It's a necessary way to avoid overheating of the dampers and overloading the ball bearings. Certainly, you could use just one spring / damper per wheel but you wouldn't reduce friction or achieve lower weight. What you would do is reduce safety and the possibility to employ two different spring settings to play with the transfer point…'

A new development about which VW was being just a little coy was described as 'a revised hydraulics system for the dampers', which was

ALTITUDE ADJUSTMENT

To counter the atmospheric challenge of the high altitudes found on this year's Dakar rally, Volkswagen put the Race Toureg 2 through a series of tests in its altitude environmental test chamber at Wolfsburg. The cross-country rally prototype was subjected to several series of tests simulating the climatic conditions found in Argentina and Chile. The objective was to adapt the engine control electronics to the extreme altitudes (up to 4700m above mean sea level) encountered during some sections of the 9578km endurance test.

In the chamber a typical Andes day was simulated in terms of temperature, humidity and ambient pressure, along with simultaneous modelling of the air flow over the vehicle at varying speeds on the integrated chassis roller dynamometer. During the tests, which spanned several days, special focus was put on an innovative component of the 2.5-litre TDi powerplant. For the action of the two-stage turbocharger a program map for different altitudes was worked out and refined to prevent possible over-revving in the thinner air.

During the rally itself, a sensor continually monitored the altitude, while the engine's electronic control unit (among other things) controlled the maximum speed of the turbocharger system. During the test, conditions at altitudes above 4000m were simulated and ECU maps for even more extreme conditions determined by means of calculations based on the data obtained. In addition to durability, the tests also focused on optimising engine output, to take into account the anticipated power loss of more than 20 per cent that was expected by the Volkswagen engineers in the highest altitudes conditions.

VW's environmental chamber was vital in ensuring RT2's performance didn't suffer at high altitude

developed in collaboration with technology partner ZF Sachs Race Engineering. Amusingly, the press release stated this was to 'improve the jumping properties of the Race Touareg', and we can take it that this alluded to improved response and control upon landing after jumps.

A further minor development involved the aforementioned new rear wishbone that altered the kinematics to increase roll stiffness and sharpen handling.

BODY DEVELOPMENT

The basic shape of RT2's body goes back to 2005 and was originally developed by the VW design studio at Braunschweig. However, the shape has since been refined with the aid of wind tunnel and CFD projects, the main aim being to optimise the various cooling requirements. Indeed, the body is festooned with cooling duct inlets, which feed the water radiator, intercooler, steering oil cooler, fuel cooler, dampers, brakes and the driver and co-driver's compartment which, naturally, are air conditioned.

Capricorn Composites in Germany manufactured the body itself, as well as the ducts. The entire carbon composite bodyshell of the 2009 car weighed in at just 50kg, representing a saving of approximately 30 per cent over the previous car. With a minimum weight of 1787.5kg this may seem a small percentage, but a tangible reduction in centre of gravity height was also achieved.

> "the carbon composite body represents a [weight] saving of approximately 30 per cent"

A further aspect of the body shape development was making the engine bonnet flatter, providing the driver with a better view of the track surface ahead.

TRANSMISSION

It goes without saying that the transmission has to be as rugged and durable as the rest of the vehicle and VW chose to stay with long-time supplier Xtrac, though the factory teams now run five-speed sequential units rather than the earlier six-speed ones, a measure brought in during preparations for the 2008 non-event to 'limit speed to a limited extent and to lower costs', according to Lautner. The FIA's T1 rules require that sequential changes may only be mechanically operated with no forms of assistance, although mechanically activated spark or injection cut is permitted.

As you might expect, four-wheel drive is permanent, with three mechanical Xtrac differentials offering selectable viscous locking. Differential set up is inevitably an area of compromise with such a range of track conditions, with the ability to not become bogged down in soft sand more crucial than optimal handling. Nevertheless, Lautner remarked that through general development of the diff settings 'we have increased the ramp angle under braking and the pre-load for a better turn in.'

With reliability ever the watchword, was VW's choice of a triple plate ceramic clutch made especially for the Dakar? Lautner: 'We haven't changed the clutch especially for Argentina and Chile. When you choose the right ratios and the right tyres, combined with a powerful engine, you don't use the clutch so often. We made a good choice before the rally and we never had any doubts about that.'

So, VW Motorsport's approach to the 2009 Dakar was simple – to hone the Race Touareg 2 into a thoroughly reliable, well set up and competitive machine. It wasn't easy, being the culmination of the previous five year's work, but history was made, both with the switch to a different continent and with the first overall victory for a diesel-fuelled vehicle.

FIRST PRINCIPLES

Simon McBeath is an aerodynamic consultant and manufacturer of wings under his own brand of The Wing Shop – www.wingshop.co.uk. In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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Flow visualisation

Smoke wands are a useful tool for studying aerodynamic effects. Here's what we discovered with our Benetton B199

Changing configurations, making adjustments and measuring data are the bread and butter of wind tunnel work, but flow visualisation also contributes to a better understanding of the aerodynamics of a racecar. So this month we're going to look in detail at some images, here and overleaf, of the Mansell Motor Sport EuroBOSS Benetton B199 as the MIRA staff waved their smoke wand over it.

Next month we begin a new series of Aerobytes focussing on a racing Mini in the wind tunnel.

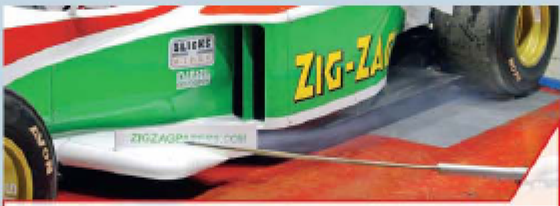
Our thanks again this month go to Kevin Mansell at Mansell Motor Sport for his help with the current series of Aerobytes.

END PLATE
With the smoke applied just inboard of the end plate, the tendency for the airflow to spill over the top of it is apparent. Some of this air heads downwards towards the lower part of the tyre, but the flip-up steers some upwards, adding end-plate downforce and reducing wheel lift

Photos: S. McBeath

FRONT WHEELS
With the smoke injected in front of the lower part of the tyre, the flow is downwards and around the tyre's shoulder and sidewall. The smoke behind shows the wheel's turbulent wake. It seems likely that some of the downforce losses that occurred with the switch to 'narrow track' in 1998 were the result of this wake impinging on the outer sections of the underfloor

FRONT WING
With the smoke plume directed incident to the front wing's leading edge, half way out from the centre of the span, the downwash ahead of the wing and upwash behind it are clearly evident. Note also how the smoke levels out towards the top of the radiator inlet

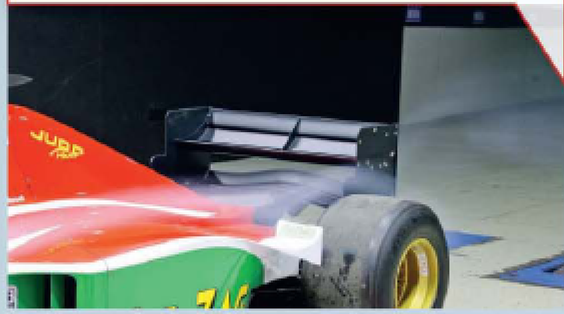


BARGEBOARD

The small bargeboard atop the aerodynamically shaped side impact structure clearly deflects the inner part of the front wheel wake outboard but it is apparent that the smoke also then aligns with the lower edge of the sidepod, but does not seem to be drawn into the low-pressure underbody region until just ahead of the rear tyre. One supposes that the side impact structure, which is shaped for positive lift, would induce an anti-clockwise rotating tip vortex along this side of the car, and this is countering the draw of the underbody, forming an invisible 'skirt'

SIDEPOD

The flip-up at the end of the sidepod is deflecting air over the rear tyre, generating an increment of downforce. However, some air can also be seen to be entrained by the wing as is evident from the upwash behind it



ENGINE COVER 1

The angle of incidence to the rear wing from the engine cover's centreline is quite steep, making the wing's centre section work especially hard. The raised centre section of the lower wing tier, which is closer to the upper tier than the outboard sections, helps keep the flow attached to the upper tier's lower surface here

ENGINE COVER 2

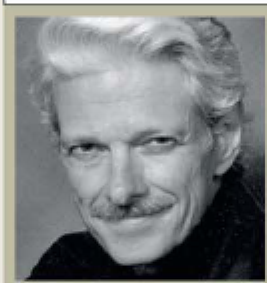
With the smoke injected just a few centimetres higher, the extent of the rear wing's upwash is clear

REAR WING

Looking from behind, the upwash is again apparent. The broadening of the smoke plume behind the upper flap suggests some flow separation is occurring, so the wing is not far from the angle at which it would start to lose efficiency

DIFFUSER

With the smoke showing the upwash from the centre diffuser section, it is clear that the lower wing tier is interacting with the diffuser, as shown by the air turning more steeply after it has emerged from the diffuser. This is another reason why the lower wing tier is the shape it is. It is also interesting to note that the flow appears to be attached in the diffuser and that the underbody flow will have been adversely affected by the boundary layer along the stationary wind tunnel floor



FIRST PRINCIPLES
Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. Here Mark answers your chassis set-up and handling queries. If you have a question to put to him
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A softer front anti-roll bar usually helps front grip and tyre wear. So what happened in the example below?

THIS MONTH:
Q1 Does a softer anti-roll bar reduce diagonal weight transfer to the rear end?
No, but the increased tyre wear and continued understeer suggests something else is at play here.

Q2 Are rubber springs a viable suspension system for a racecar?
Er, no...

Chasing a push

Q1 I work with a road-racing Mazda RX-8, and recently we have been experiencing high front tyre wear. It was never previously an issue but, in preparation for a recent race, a softer front anti-roll bar was fitted to the car and a bit of rake was added. Our front tyre wear was measurably poorer at that event. It is my suspicion that the softer front bar resulted in less diagonal weight transfer to the rear and, consequently, more front tyre wear. Do you have any thoughts on the subject?

A Anti-roll bars do not transfer wheel load diagonally in the sense of transferring it from one wheel of a diagonal pair to the other, and they do not transfer it front to rear. We might say they transfer wheel load diagonally in the sense that they transfer it from one diagonal pair to the other diagonal pair. Putting it another way, they change the dynamic diagonal percentage, but not the diagonal front, rear, right or left percentage.

A couple of questions back to you: the RX-8 has double wishbone suspension in front, correct? Did you increase the rake by raising the rear, or by lowering the front? How do your static camber and toe settings compare, before and after the change? Where do the front tyres wear - ie what part of the tread?

Ordinarily, a softer front bar, or a stiffer rear, helps front grip and front tyre wear. Does the car in fact have less understeer?

QUESTIONER'S RESPONSE
The chassis we are running does indeed have a double wishbone front suspension. When we increased the rake, we added height in the rear (we try to run the front as low as possible at all times). We made sure to set the camber and toe to the same setting as before our changes and the tyre wear was strikingly even across its full width.

As far as balance is concerned, we have been experiencing mid-corner understeer for the entire life of the car, and that did not go away with these changes. It didn't get any worse though.

A The fact that the understeer wasn't affected by the anti-roll bar change, together with the fact that it is most evident mid-turn, suggests that something in your front end is running out of travel at full roll.

The coilover or shock could be bottoming out, or it could be something else. Other things that can happen in lowered cars, particularly when you've found a bit more bump travel at the shock, include ball joints (usually upper) running out of travel and control arms (usually lower) hitting something, like the frame. Sometimes tie rods or anti-roll bars hit things, too.

Do you have travel indicators on your shocks? If so, and if they don't indicate that the shock is bottoming out, take out the springs, disconnect one end of the anti-roll bar, and move each front suspension through its indicated travel with a jack, then a bit beyond that. See if anything binds or hits and check to see if the steering still works freely.

If everything checks out at full compression, try the same thing at full droop. In lowered cars, it is less common for the inside wheel to top out than for something to bottom on the outside one, but this can happen in cases where a shorter shock has been used to get more bump travel.

There is one other possibility, particularly if you are satisfied that nothing is binding or bottoming out.

In some cases, mid-turn push can be caused by the brakes failing to release as they should, and dragging for a time following trail braking. This can even be driver induced, when a left-foot braker unwittingly fails to release the pedal completely. If you can rule out the driver-induced situation, it can be a bit hard to tell if the brakes are releasing slowly. One quick test is to try hard cornering, not immediately preceded by braking. That is, either test on a skid pad, or drive into a turn fast enough to put the car at the limit going through the turn, but approach the turn at such a speed that you don't have to brake. If the car still pushes, you can probably rule out the brakes. If the push does not appear when you don't brake immediately before, suspect dragging brakes.

Rubber spring suspension

The original Mini's rubber cone suspension – no wonder the driving experience has often been likened to driving a trailer!

Q2 I wonder if you are familiar with torsion rubber suspension systems, as used on some trailers. For example, the Henschen dura torque axle system. There really is just a single trailing link with this system, but where is the roll centre? Is it at the centre of the axle tube? Is it essentially fixed? Is the virtual swing arm length infinite?

Has anyone ever tried to use an axle like this on the rear of a front-wheel drive vehicle?

A This system is a pure trailing arm system with no anti-roll bar. The front view swing arm length is infinite, or undefined, while the side view instant centre is at the pivot axis. This creates a system with no camber change in ride, no camber recovery in roll, very little geometric anti-roll and a lot of geometric anti-lift in braking.

The roll centre is not at the pivot axis, it's at ground level in the unrolled condition, and slightly above ground level when cornering - ie with some roll and with more than 50 per cent of the lateral force generated by the outside tyre.

This particular design of trailer axle uses rubber in a combination of compression, shear and torsion as the ride springing medium. The assembly includes a square tube crossmember that mounts it to the frame. Each trailing arm has welded to it a piece of square bar that is inserted into the crossmember. The square bar is sized so that its cross-sectional width across points is slightly smaller than the crossmember tube's inside width across its flats. In other words, the square bar is just small enough to fit inside the square tube and turn.

As assembled, the square bar sits at a 45-degree rotational angle inside the tube, its points centred on the tube's flats, leaving four roughly triangular cavities between the flats of the bar and the interior surface of the tube. These cavities are filled with rubber.

One might suppose this would be done by bonding extrusions to the metal, and by adding some metal retention system to keep the bar in the tube, but that's not what Henschen does. It buys round rubber bars (or cords) that, as purchased, would not go into the cavity. They then squash them to the shape of the cavities in a hydraulic press and freeze them in that form with liquid nitrogen so they hold their molded shape until they thaw.

> "One problem with using rubber as a spring is that it cold flows under sustained load"

The rubber pieces and the trailing arm with the square bar welded on are assembled into the crossmember while the rubber is frozen. When the rubber thaws and tries to resume its former shape, it becomes an interference fit in its cavity, which is deemed sufficient to retain the trailing arm to the crossmember with no additional hardware.

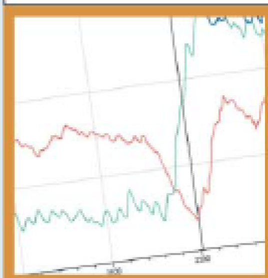
It would be possible to add a torsion bar connecting the square bars, to serve as an anti-roll bar, but this is not done. It would also be possible to add hydraulic shocks, but that is not done either. Instead, the system relies on the internal hysteresis of the rubber for damping. The result is a very simple and compact suspension system.

This exact design has not been used at the rear of a FWD vehicle, but certainly a trailing arm suspension with rubber springs has. That's what the original Mini had.

However, one problem with using rubber as a spring material is that it cold flows under sustained load, causing the suspension to sag. The best application for rubber springing therefore is a light trailer that sits unloaded between trips, or a light motorcycle or scooter that sits on its centre stand with the suspension extended when not being ridden.

Probably the biggest car to use rubber-in-torsion springs was the Tucker. I'm told that owners of the few surviving Tuckers store their cars on blocks with the suspension at, or near, full droop to keep the cars from sagging. Sagging is less of a problem when the car is light compared to its cargo, the suspension is stiff and longevity is not a high design priority. That's how the Mini got away with rubber springs.

With or without rubber springs, a suspension for a car still needs proper dampers. Rubber does provide some internal damping but, in any situation, a car suspension needs real dampers.



FIRST PRINCIPLES

Databytes gives insights to help you improve your data analysis skills each month as Cosworth's electronics engineers share tips and tweaks learned from years of experience with data systems. Plus we test your skills with a teaser each month.

To allow you to view the images at a larger size they can now be found at www.racecar-engineering.com/databytes

Asset management

Not only do tyre pressure monitoring systems produce invaluable data, they can also help reduce expensive failures

With the drive to reduce failures and their associated costs, tyre pressure monitoring systems (TPMS) are becoming ever more important in the management of a racecar. There are two primary benefits to using the system:

1) Performance analysis – data enabling the improvement of tyre use.
2) Safety – data giving a warning before catastrophic failure.

HOW THE SYSTEM WORKS

A TPMS operates with the following set of sensors and units:

1) Temperature and pressure sensors with integrated transmitter (wheel valves).
2) Multiple receiver antennae.
3) Central ECU.
4) Loom from receivers to ECU.
5) Loom from ECU to chassis logger.

Each wheel rim is fitted with a valve assembly that incorporates a temperature and pressure sensor and then balanced. The temperature and pressure measurements (in degC and absolute bar or psi) are then transmitted via a radio frequency (typically close to 433MHz) to a receiver antenna. In the case of an open-wheel car it is generally sufficient to have two receivers, but in a closed cockpit car it may be prudent to run four receivers to achieve good reception.

The receivers transmit data to a central ECU via a standard wiring loom and the ECU handles all the software configuration for the system. A comprehensive tyre pressure monitoring system will have the following features:

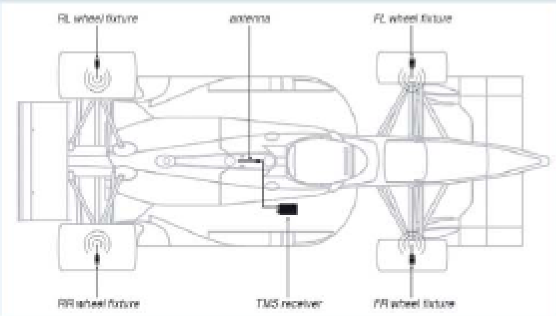
1) Wheel permit list – locking down sensor serial numbers to a particular car and team.
2) Wheel position list – making it easy to define the position of each wheel sensor on the car.
3) CAN addresses for each channel within the data stream that goes from the TPMS ECU to an external data logger.
4) Alarm thresholds – defining soft and hard warnings for pre-set pressure and temp parameters.

The systems have developed so far that the actual transmission of data is far removed from a typical set up that is constantly on. To reduce power consumption, the systems only transmit data when the wheels are rotating (sensing a centripetal acceleration), so when stationary, sensors transmit data packets at a low rate (usually every 30 seconds, but can be changed).

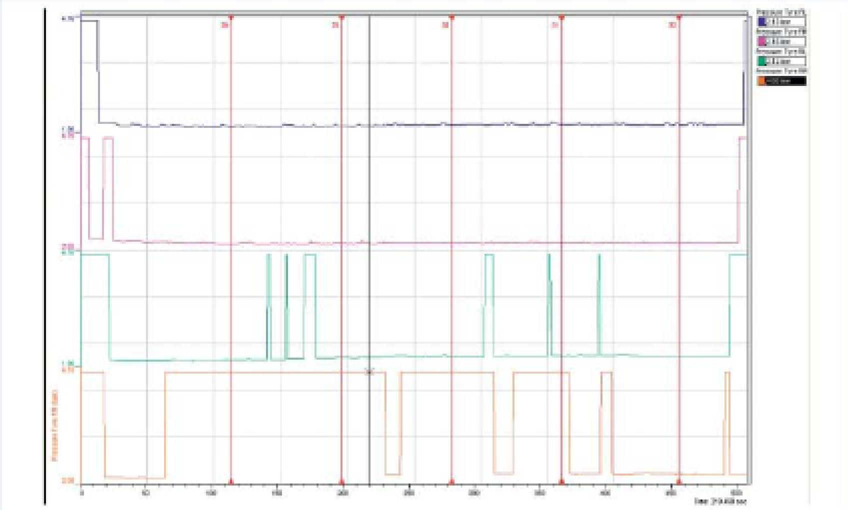
When in operation during a run, the system typically transmits data at 1Hz, which is sufficient for the most common data analysis used in motorsport. The temperatures are measured at the carcass, so the bulk of the rubber won't heat up at such a high rate as the outside surface.

Outing		Pressure Tyre FL (bar)	Pressure Tyre FL (bar)	Temperature Tyre FL (°C)	Temperature Tyre FL (°C)
Lap	Lap Time (sec)	max	min	max	min
29	94.020	1.17	1.11	84.00	82.00
30	93.860	1.20	1.12	83.00	82.00
31	93.890	1.21	1.15	84.00	83.00
32	99.420	1.21	1.15	86.00	84.00

Typical data acquired from a TPMS over a number of race laps



The basic components of a TPMS and their typical placement on a racecar



A max pressure reading, as shown above, should be checked for validity. Here it is most likely due to a low battery

ALARM SETTINGS

As pressure can decrease very rapidly in a tyre blow out, the system hardware will handle this by processing the data at a higher rate than the rate of transmission. Hence, the system will 'look out' for a blow out at 50-100Hz to flag an alarm.

When used correctly as a safety system, a TPMS system might have the following alarm settings, to alert the engineers and drivers of tyre problems:

- Soft warning when pressure is below 1.7bar – alerts engineers that the tyres are outside their optimal operating range.
- Soft warning when pressure is above 2.1bar – alerts engineers that the tyres need bleeding.
- Hard warning when pressure is below 1.6bar – indicating the driver will be at risk if racing at full pace.
- Soft warning when pressure loss gradient is inferior to 0.01bar per second – indicating a slow puncture.
- Hard warning when pressure loss gradient is inferior to 0.05bar per second – indicating rapid deflation or tyre failure.
- Soft warning when temperature is above 105degC – indicating that tyres are overheating.
- Soft warning when temperature is below 70degC (optional).

DATA ANALYSIS

When looking at TPMS data it is important to make a key initial assessment of values during an outing. In other words, a routine systems check. This enables you to confirm that the data on screen is reliable and can be used for analysis. This will be useful to:

- Check all maxima and minima (excluding the start stop values) – this gives you an indication of the range the pressure and temp sensors have measured.
- Compare the max pressure value with the sensor default failure value – this points to an occurrence of low sensor battery or a problem with the sensors (sensors will read max pressure when there is a fault).
- Find the location of max and min – this will tell you if the values are measuring a real situation.
- Check any gaps in the data (discontinuities) or very rapid changes – keep an eye for correct operation of the system.

For example, the screenshot above shows a plot of data where max pressure is 4.63bar, which is the maximum value the system can read. This can most likely be attributed to a low battery in one of the sensors, rather than a sudden change of tyre pressure.

Progressing on to the performance analysis, some ideas for a methodical approach are to pick meaningful points in the data for some statistical analysis. You can generate a summary table (automatically generated in Excel if you are using Pi Toolbox) or, if you are noting down values by hand, use your judgement to exclude values that do not belong to the 'real world'. If automating the procedure, you can use a maths engine to generate maths channels that will remove data outside of set conditions.

The data may initially look a little bit dry but, after a few sessions, a data and race engineer will be able to relate to it and use it to their advantage. The difference between the maximum and minimum values gives an indication of the consistency of the driver with this tyre choice. A low variation also allows us to assume the tyre is operating in its preferred temperature window.

RACE STRATEGIES

TPMS are a great combination with real time data (telemetry) on the pit wall or inside the garage, enabling the engineers to keep an eye on driver safety and to monitor how the tyres are behaving during each stint: are they a good set? Is the driver leaning too hard on them? Are they dropping off too fast?

Not every series is blessed with open-minded rules about real-time data, so the system is also useful in the more traditional scenario of downloading a car. A methodical approach to tracking tyre sets with outings will enable the data engineer to write notes for the race engineer that link the set up with the tyre performance. For example, 'dropping' the pressures by 1psi (0.07bar) will influence the pressure and temperature pattern across the run for all four tyres.

Whilst most drivers may not find much meaning to lines of data on a screen, statistical data on a sector-by-sector and lap-by-lap basis will form reliable information to back up the driver's feedback on the car's handling, balance and speed.

CONCLUSION

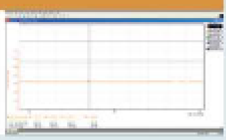
Armed with the knowledge of how a TPMS works, any serious team can evaluate its benefits to the safety and performance of a racecar. While it may be a large investment, it is a system that can be used in different cars where the original chassis loom allows.

As for the driver, the sensors are some of the most critical parts of the racecar, since they evaluate the performance of the rubber that keeps him or her on the track.

CHALLENGE

Test your own data analysis skills by going online at www.racecar-engineering.com/databytes

Here you will find a monthly challenge set by Cosworth, together with an explanation of the answer by one of their data engineers.



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LAT

Ad-Vantage Aston

When Aston Martin decided to enter GT2, it took a different approach to its competitors and the result is a competitive, cost-effective racecar

BY IAN WAGSTAFF

When the Aston Martin Vantage V8 GT2 car first appeared in early 2008, the Le Mans class-winning GT1 DBR9 was over half way through its life. 'We needed to look towards the future,' said Aston Martin Racing (AMR) team principal, George Howard-Chappell.

'We put our toe in the water to see if the V8 Vantage would make a GT2 car,' recalled AMR race engineer David Wilcock. 'At that point in time we had GT1, GT3 and GT4 cars, the first two based on the DB9, the GT4 on the V8. We had also previously built a rally version of the Vantage called the Rally GT, which was aimed at the gentleman rally driver.

'GT2 has been up and coming for a little while and we had a hole in that area, so we built a mule car at the end of 2007 to assess where we could pitch in. We took a standard engine and increased the performance to where we thought a GT2 car could be. We also tried to use as many generic parts from the GT3 DBRS9 as we could, including the gearbox that was already proven. In terms of chassis, the difference between the DB9 and the Vantage V8 is small, the latter is just a bit shorter, so it was a simple job to put the mule car together.'

The outcome of the work with the mule car suggested to AMR that it could do 'a reasonable job' with a GT2, so a business plan was put together. The mule car was then converted into the first GT2 test car, albeit with a new valvetrain for the engine.

COMPETITION BASE

It is to Aston Martin's advantage to have the Vantage as its 'competition base', added Howard-Chappell. 'We see the social, economic and political climate pushing manufacturers towards racing more efficient, lighter, less powerful cars. It may no longer be reasonable to have over 600bhp cars racing in 2013. Things are changing and I think the racing community needs to wake up to that, and a lot of the car manufacturers already have. It's no good burying your head in the sand and thinking it is fine to build racecars based around current, high-end sports cars.

'Therefore, we wanted to do something based around the V8 Vantage. The fact that the FIA was changing the GT2 category to become a performance-balanced formula meant we decided to go that route and build a car at an economic price.'

'It was slightly different to the way in which we have done cars in the past because we basically picked up the rule book and asked, "how do we build a car that can be sold at a sensible price and still be competitive?" rather than "here is the rule book, what is the most you can do to arrive at a performance level?" We were not arrogant enough to say we could build an economic car that would be immediately competitive with the established Porsches and Ferraris.'

A roadgoing Vantage V8 is considerably cheaper than a street Ferrari 430 and, unsurprisingly, at a performance disadvantage. However, GT2 rules allow it to compete.

'The main problem with the development of the GT was that we were always up against time,' said Wilcock. 'This is a handicap formula so, from the very early phases, this was not going to be an out and out thoroughbred racecar. We were looking to obey the rules, within the limits, and make the most of performance opportunities where possible under given budget restraints.'

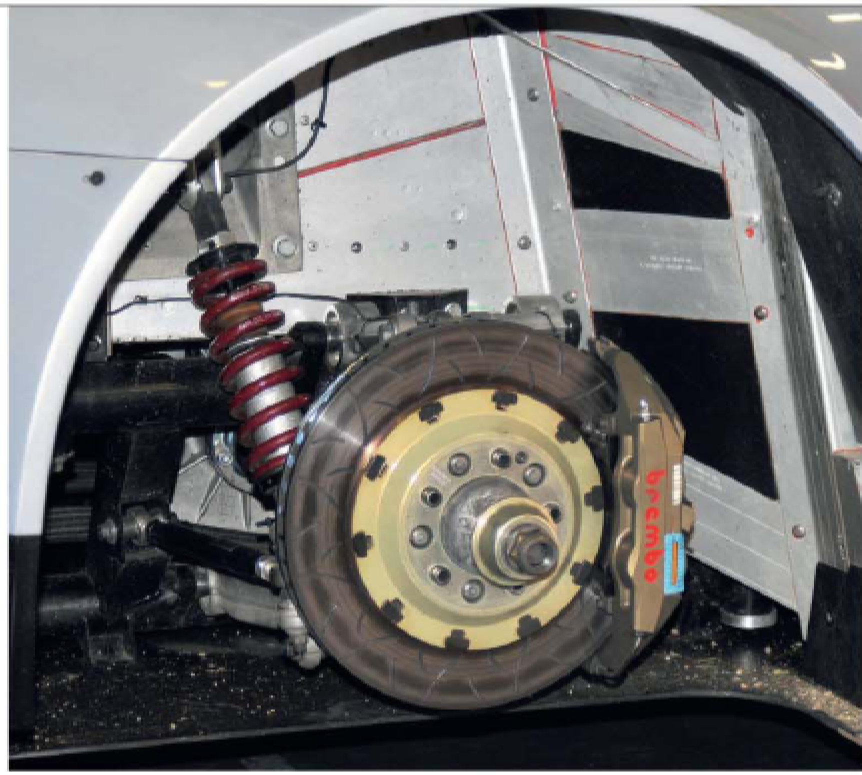
To keep costs down, the engine is a bored-out version of the stock 4.3-litre, aluminium V8, now displacing 4.5-litres

COMMON ENGINEERING

It was possible to share many common parts with other AMR products but, when the homologation process took place, the FIA expressed surprise at what AMR had not taken advantage of. 'The main problem was to respect GT2 design,' explained Wilcock. The original GT2 concept was to take a road car, put in a safety cage, a set of wider wheels, tune the engine a little and go racing. Ferrari and Porsche have taken the formula to such a point that the cars are little slower than GT1 and, as Wilcock pointed out, 'to get that kind of performance costs an awful lot of money. We wanted to produce a competitive car, reasonably priced.'

As such, the Vantage offers a reasonable donor engine – a compact, relatively modern V8, and the aluminium chassis is very similar to a DB9, so the rollcage can be a simplified and adapted version of that used in the DBR9. 'The rollcage-to-chassis integration was nothing as intricate as the DBR9, which was done from components, whereas with the GT2 we just take a Vantage bodyshell and convert it,' he said.

The Vantage GT2 bodyshell is almost entirely carbon fibre, with a CFD-designed GT1 rear wing, flat floor and a simplified version of the DBR9 GT1 rollcage



Suspension uses standard double wishbones and mildly modified uprights, Koni dampers and steel Brembo brakes

> " the social, economic and political climate [is] pushing manufacturers towards racing more efficient, lighter, less powerful cars "

The suspension is also similar to the DB9, with double wishbones and standard uprights all round, although there is a small change to the position of the rear pick-up points and a slightly modified production subframe. The gearbox casing is also standard, though 'we have changed the internals of the gearbox,' admitted Wilcock.

The front upper and lower wishbones have only been changed for packaging reasons, while the rears have remained fairly standard. The suspension of the DBRS9 had already been modified slightly for its wider body and camber adjustments, so the GT2 car shares many of its parts, but because the GT2 is allowed a lower ride height the geometry had to be corrected with some light machining of the front uprights. Use is made of 'tried and tested' coil springs over Koni adjustable dampers, while the standard wheel bearings have been retained to keep the costs down (a wheel bearing for a GT1 Aston Martin costs about 25 times as much as that for a GT2). The steel brakes feature Brembo six-piston callipers at the front and four-piston callipers at the rear, and an endurance option is available with a wider disc and thicker pad.

Having used OZ wheels for its GT1 programme, AMR is making use of less expensive, forged aluminium, centre lock BBS wheels for the GT2. The BBS wheels have a slightly stiffer rim for their spoke pattern.

TRIED AND TESTED

The original Vantage engine had a displacement of 4.3-litres. This has now been replaced by a 4.7-litre unit, which is used by the newer GT4 racing version, the Vantage GT4 that has replaced the 4.3-litre N24. Because the 4.7-litre engine was not in use when the GT2 project was started, this uses a 4.3 bored out to 4.5-litres and fitted with an uprated valvetrain. 'The firing order puts some nasty harmonics through the valvetrain, which caused some problems in the early phases,' recalled Wilcock, 'but with budget and timing restraints the standard crank was still maintained.

'We have a tried and tested gearbox from the DBRS9, which is capable of handling another 20 per cent more power and torque,' he continued. 'It made sense to share this, using additional gear ratios to tune it for the choice of circuits.' Use is made of a Graziano gearbox, popular at

TECH SPEC

ASTON MARTIN GT2

Configuration: front engine, rear-wheel drive

Chassis: bonded aluminium chassis from the V8 Vantage road car; Aston Martin Racing manufactured, aerospace specification steel rollcage built to FIA regulations

Bodywork: carbon fibre bonnet, wings, doors, tailgate, front and rear bumpers, sills and rear quarters, roof is standard road car aluminium panel

Aerodynamic package: carbon fibre front splitter, flat floor, rear diffuser, CFD-designed rear wing

Engine: AMR 4.5-litre, production-based V8 in 90-degree configuration with all aluminium cylinder block and heads, four valves per cylinder, dry sump lubrication and racing exhaust system

ECU/data system: Pectel SQ6 engine management; Pi data system

Electrical: Bespoke AMR-manufactured loom

Transmission: six-speed Xtrac sequential transmission transversely mounted on the rear axle, air and oil cooled with competition clutch

Suspension: double wishbones front and rear, coil springs over Koni adjustable dampers; front and rear suspension adjustable for corner weights, ride heights, toe and camber settings

Wheels and tyres: forged aluminium centre lock BBS wheels, 10.75 x 18in front, 11 x 18in rear

Brakes: Brembo six-piston calipers front and four-piston rear

Weight:

FIA regulations – 1150kg

ACO regulations – 1175kg

this level and also, incidentally, what is installed in the Ferrari 430. To this is fitted a Holinger straight cut, six speed gear cluster. Likewise, the CTG (like AMR, Banbury based) propshaft is upgraded, although the standard torque tube is still used.

Due to its smaller overall size and overhangs, a special cooling package was allowed that exits through the carbon fibre bonnet

BODYWORK

One only has to look at the bluff body of the Vantage to realise that it is quite 'draggy'. Aware of this, a CFD analysis was carried out by TotalSim to evaluate the wheelarch shape and the rear wing shape and position. The results were then correlated in the MIRA wind tunnel.

The biggest issue for the carbon-bodied (all apart from the roof) Vantage was that it was quite small when compared to the opposition, in particular the overhangs. Because of this, cooling has been an issue, so a waiver was required to allow a cooling package that exited through the bonnet. The small overhangs also mean the effectiveness of the rear wing is reduced, so AMR has been allowed to use a low downforce GT1 version in the GT1 position in order to generate competitive forces. 'This does mean that people look at it and say, "that's not a GT2 car!" said Wilcock, 'but they are missing the point.'

> "this was not going to be an out and out thoroughbred racecar"

Interestingly, the number of waivers in the series appears to be growing, to help make more cars competitive, and Wilcock smiles when he says 'the waivers seem to be becoming a bigger document that the homologation papers!'

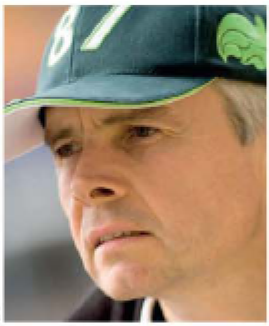
UNDERSTANDING...

What is of particular note is that this is the first front-engined Sportscar the FIA has had to homologate for some time. 'They wanted to take their time with this and understand all the problems we have had along the way. They have been understanding with the problems we have encountered.' One of these was the placement of the exhaust. Being front-engined, the exhaust would ideally exit out the back, but when the rules mandate a flat-bottomed car that would make cockpit temperature unbearable. After consultation with the FIA/ACO, side-exiting exhausts were agreed upon, which meant the modification of a few panels.

The chassis and powertrain of the DB9 and the Vantage are assembled independently, with the engine built on the subframe, the gearbox positioned in its subframe. When all the suspension and the uprights are fitted, the last task is to mate these two sub-assemblies together, with the torque tube connecting the two. This meant that one area that was always going to be a problem for the racing versions was serviceability as, once the two halves are connected, it becomes difficult to service either the gearbox or engine individually. Again, waivers are assisting AMR in overcoming this problem, including the ability to have some additional joints in the structure. Without these it could take between seven and eight hours to replace the engine. 'We need to get that down to two or three,' observed Wilcock. At the time of writing, this area of the car's development was still in progress.

TAKING IT TO THE TRACK

Bringing the new GT2 car to market was extremely difficult within the time limits, so the plan was to supply one car for the Barwell Drayson team to run in the ALMS using E85 bio-ethanol, an FIA GT championship car for Gigawave and a third car to James Watt Automotive (JWA) for the LMS. A greater volume was promised for the future. Although it did not start the race due to an oil leak, a James Watt-entered, factory-owned car made its debut in practice at Barcelona in early April. The project was under some stress at the time so AMR loaned JWA its test car for the event as its own was not ready.



LAT

Lord Drayson of Kensington, the Minister for Science and Innovation

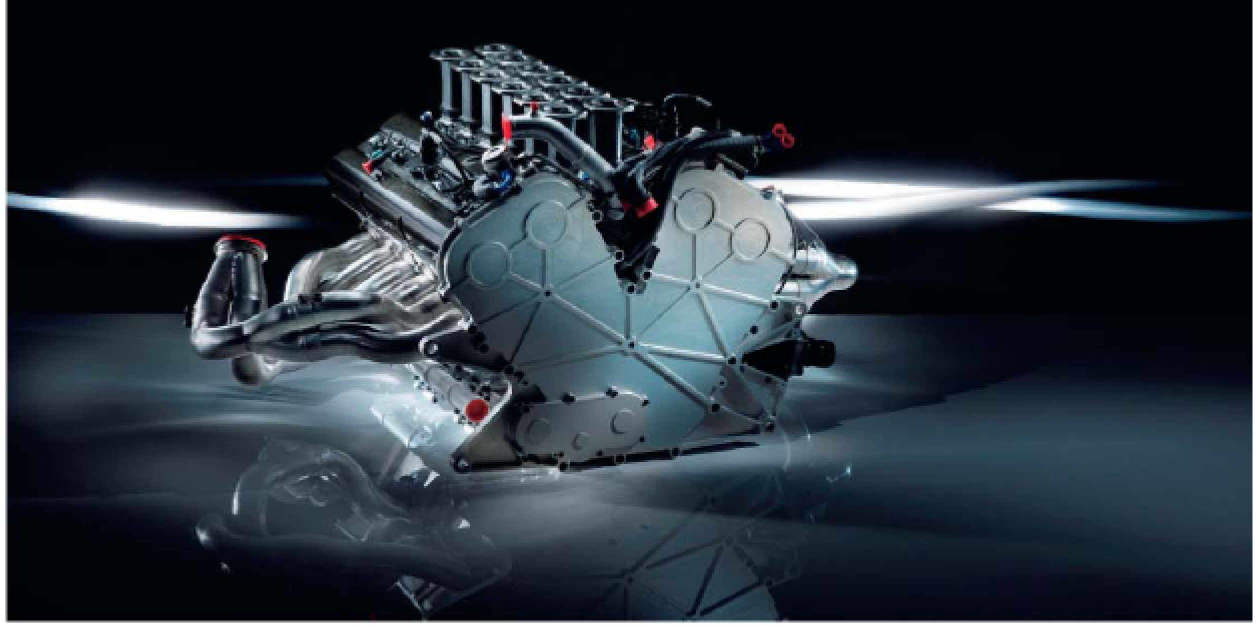
Paul Drayson started off the ALMS season with his GT3 DBRS9, his new GT2 appearing for the first time at Long Beach, but saving its best performance of the year until the last round of the ALMS at Laguna Seca, where it finished seventh in class. JWA's own car finally appeared at the last round of the LMS at Silverstone, while the Gigawave GT2 never materialised. A works car also competed in the last two rounds of the 2008 FIA GT Championship. At Nogaro the car was still some way off the pace, though adjustments were made for Zolder that made it a lot more competitive. The car had the fastest time of all the GT2s in the session before qualifying and qualified fourth, before a first-corner accident in the race ruined what could have been a good race result. 'It showed us where we needed to pitch in for 2009,' said Wilcock.

The negative with Drayson's bio-fuelled version was that more weight had to be carried because the fuel flow rate is higher. Therefore, the car starts a race heavier with a larger (110 litre) fuel cell. Howard-Chappell observes that the potential in the fuel is probably greater than for conventional petrol, but AMR does not specifically tune the engine around bio, merely changes the fuel lines and fits o-rings to suit the fuel. The move was led by Lord Drayson but, said Howard-Chappell, 'we totally support it.'

'Compared to the GT1 there is a lot more that is standard on the GT2, partly by regulation and partly by choice,' he summed up. 'This is not just about cost, being closer to the road car is something we are interested in. It's the principle and the philosophy of our approach to the GT2 car... It goes to show just how good the road car components are.

'In really basic terms, the Vantage GT2 is half way between a Vantage GT4 and a DBR9. I think we have approached it in a sensible way for a GT2 programme, that is going to produce a car that is economical to purchase and run.'

Direct drive



Direct injection is not a new idea, but making it work reliably on a racecar without spending a fortune is. Here's how Aston Martin approached the challenge

BY LAWRENCE BUTCHER

The pinnacle of endurance racing, the Le Mans 24 Hours, has been dominated by diesels for the last four years, but this year the gap between the oil burners and the petrol-powered cars was drastically reduced. This reduction was in part a result of the ACO's revised equivalency formulas, but credit must also be given to the engine powering that petrol car – an Aston Martin direct injection V12.

Aston Martin was the first manufacturer to take advantage of the 2008 ACO regulations, making it feasible to run a production-based engine competitively in the LMP1 class. The GT1-sourced 6.0-litre V12 made its debut in the Charouz Racing System Lola B08/80 chassis run at the 2008 Barcelona LMS round. Though the engine was successful, putting the Lolas at the top of the petrol pack, it was by no means optimised for use in a prototype. It was, in effect, the GT1 engine from the DBR9 with an airbox fabricated to suit a prototype. However, with the emergence of a Prodrive-developed Aston Martin LMP1, the DBR001 (based on a Lola B08/60 tub), the decision was taken to develop the GT1 engine into a unit more suited to an LMP car.

Whilst the regulations limit the extent of modifications allowed on a production-based unit in a prototype, Aston Martin has been able to make considerable gains through the in-house development of a direct fuel injection system for the V12. Direct injection can bring many benefits to a race engine, especially one destined for endurance racing, the major factor being an increase in efficiency. This is gained in several ways: firstly, you achieve minimal wall wetting within the cylinders, making mixture control from cycle to cycle very repeatable. Secondly, the fuel being injected directly into the cylinder evaporates, creating a cooling effect, allowing for an increase in compression ratio without the risk of detonation. Finally, the fact that the fuel does not have to pass through the inlet port increases the gas exchange efficiency, as the port flow is purely gaseous, with no liquid present. This increased efficiency means the engine can be tuned either to produce more power or to produce the same power output as a port-injected motor but with a reduction in fuel consumption. However, the key to making such a system work effectively is an in-depth understanding of the combustion chamber dynamics.

Jason Hill, Aston Martin Racing's chief engineer, was involved in the project from the start. 'It was quite a challenge for us, and in fact we started working on the system before the project was actually signed off, beginning development in July of last year. Obviously, we have made some general improvements, and have tuned the engine to run more efficiently at the engine speeds given to you by the restrictor sizes for a prototype. But the most significant change has been the GDI system. That is where we have focused our development between this year and last year.'

Direct injection is by no means a new idea, having appeared in WW2 aero engines and in the 1940 Alfa Romeo 6C 2500. However, making such a system work on a modern race engine requires a great deal of investment, with Porsche the only manufacturer to field a system on a current petrol LMP. Given the relatively

TOP END DEVELOPMENT

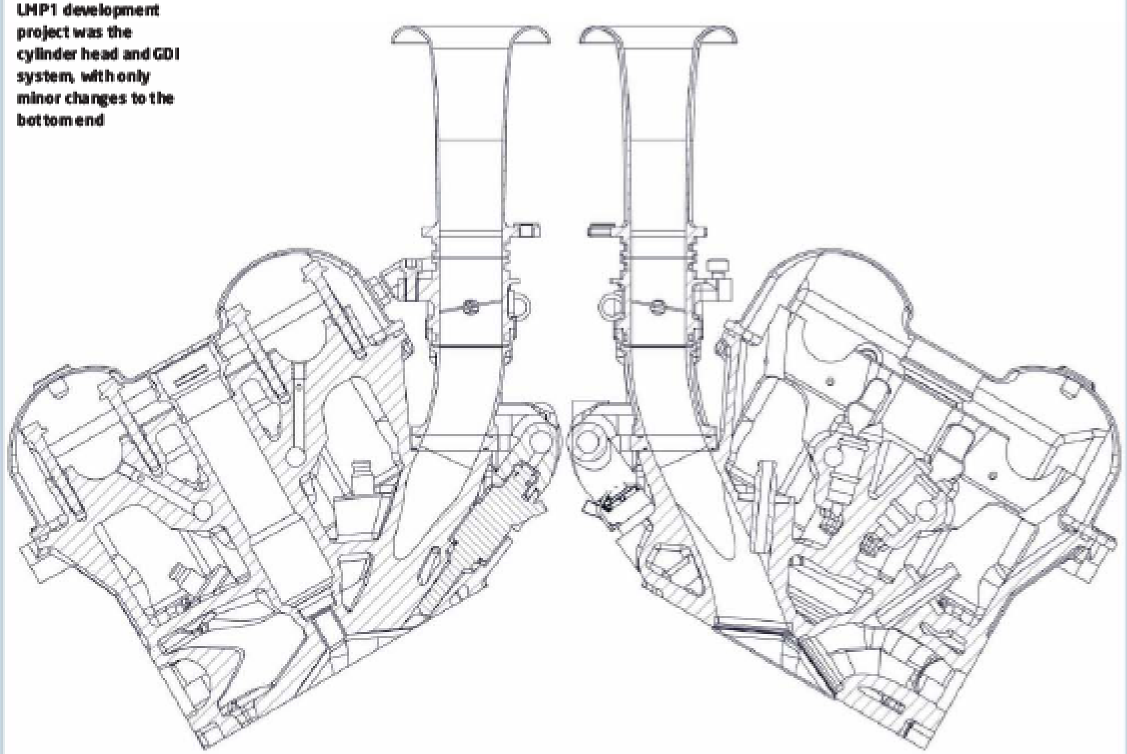
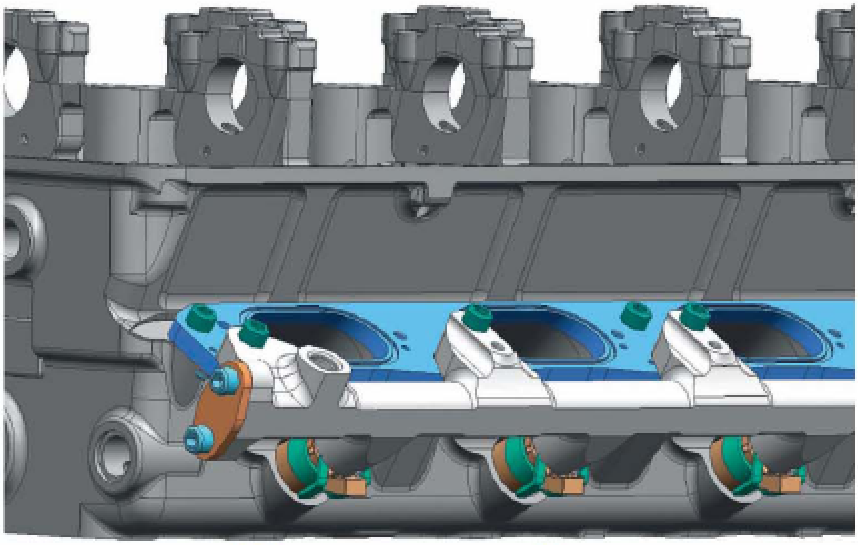
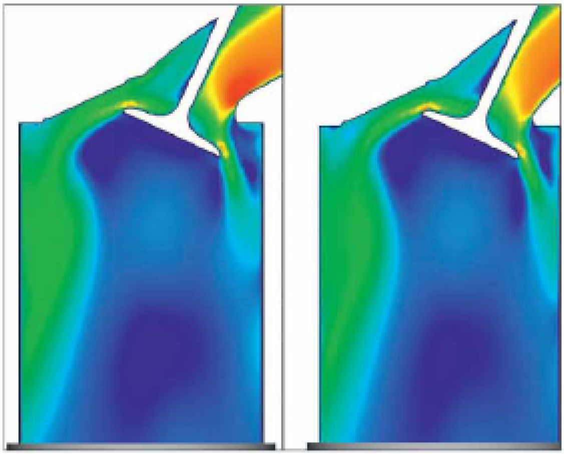


Figure 1
The main focus of the LMP1 development project was the cylinder head and GDI system, with only minor changes to the bottom end

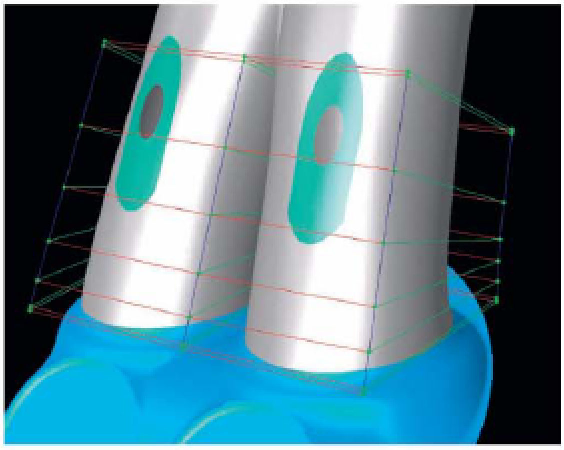
The direct injection Aston Martins were the highest placed petrol-fuelled finishers at the 2009 Le Mans 24 Hours



The majority of development work on the GDI system was completed virtually, so very few prototype parts were produced, reducing both cost and time invested



Optimisation: on the left the '08 inlet port flow, on the right the '09 design



Simulation software was also used to perfect flow and tumble in the ports

limited resources available to Aston Martin, development had to be approached in a measured fashion to ensure the system was feasible. Hill: 'We have taken our normal pragmatic approach to the development. So, as opposed to just going in all guns blazing and trying all the different possibilities, we have had to concentrate on really winding back from this race [Le Mans], putting stakes in the ground and setting dates so we knew exactly where we were.'

Perhaps unsurprisingly, a large proportion of the engine's development was done through simulation. Utilising GT Power software for general engine simulation and TotalSim, in conjunction with Sculptor from Optimal Solutions for the CFD simulation, the team was able to extensively develop the engine without producing any physical components. 'Pretty much we are on our first iteration of cylinder head geometry, combustion chamber shape in the actual shape we have made and we have done all of that development through simulation,' continues Hill. 'We are in fact on only our second type of injector.' One of the key functions of the CFD analysis was optimisation of the airflow into the combustion chambers, ensuring the correct tumble of the air / fuel mixture to create a homogenous cylinder charge and maximise efficiency.

"We have taken our normal pragmatic approach to the development"

While the system was by no means rushed into service, Hill admits it is still in the early stages of development. 'We are early on in the curve of development for GDI, but so far we are reasonably pleased with what we have achieved and where we have arrived at. I think we are nowhere near fully optimised on the system yet, but we are in a position where we are comfortable to race it.' Although the engine had been run in testing, both on track and on the dyno, Le Mans was its first true reliability test. In fact, two of the Charouz cars didn't even receive their direct injection engines until after the qualifying session! Despite this, the race was a testament to Aston Martin's development programme, with all three cars finishing without any major technical problems. The differential between the petrol and diesel cars was reduced from around five seconds in 2008 to nearer two seconds in 2009, with nothing in it in terms of top speeds. Given this, one wonders whether if the team had works backing on the scale of Audi and Peugeot they could have been competing on a level playing field for the overall win. One thing is clear: Aston Martin's V12 has a lot more to give, and the potential to slash diesel's dominance in endurance racing.

Feeling electric

Racecar Engineering takes a drive into the future behind the wheel of the winner of the British Formula Student alternative propulsion class

BY SAM COLLINS

Everybody knows the future of motorsport is going to be different, the only problem is that nobody seems to know the format it will take. Hybrids, electric vehicles (EV), bio fuels, hydrogen and high efficiency petrol and diesel engines are all mooted. At some point, every series, every team and every driver is going to have to face the question and some are already opening up the rules to allow different solutions.

One area of motorsport that is ahead of the curve though is the British version of Formula SAE, Formula Student, having already introduced a new class called 1A for all of the aforementioned technologies. During this year's event, held at a soaking wet Silverstone circuit in July, one car delivered a shocking result, the UH12A built by the University of Hertfordshire in England.

It was the best result in the modern era for an EV against petrol opposition, not just in FSAE competition, but in motorsport as a whole. Because of this, we were interested to find out more about the car. And when faculty advisor Howard Ash and team leader James Major invited us to give the car a try, we gladly accepted, which is how I came to find myself at some ungodly hour of the morning at the Rye House circuit in Hertfordshire.

> “probably quicker than any of the previous FSAE-rules cars I've driven”

Electric cars like this make hardly any noise, so finding venues for them to run at is far easier than with a conventional powerplant. Benefit number one.

But are electric cars really green? After all, the batteries are nasty things to manufacture and they're near impossible to dispose of, right? Not according to Major: 'That's not the case; the chemistry of these cells is such that there is only a trace element of lithium in there and the majority of the cell make up is just copper and aluminium. They will do at least 3000 cycles and are highly recyclable,' he says enthusiastically. With 240

Even at just 70 per cent power speed was not an issue. However, the almost complete lack of noise and vibration made it easy to go into corners too quickly, but this is something a good driver would quickly adapt to and master!

The slogan on the car below pronounces it the 2009 Class 1A winner – that's the UK Formula Student class for alternative fuels

of these LiFeBatt lithium-iron phosphate cells supplying energy to the 144V powertrain, which consists of twin direct current motors, this should be quite a potent machine. That is, if I can fathom out how to drive it.

I get to drive a lot of competition cars in my job, from large American Stock Cars to lightweight Sports Prototypes, and you always get a comprehensive briefing first, but this one was disarmingly simple. 'How do you know when it's running?' I ask. The answer comes with a smirk. 'The light is flashing and you are moving!'

The controls are incredibly spartan, just an on switch and a starter button, and what looks like a fire extinguisher pull, but I'm informed is actually the off switch. There is no gear shifter or clutch, the steering wheel is an off-the-shelf unit with no knobs or fairy lights to speak of, and there are no dials. The footwell is similarly basic – just a 'throttle' and a brake.

'It's really simple, just big karts really,' smiles Major, then he simply says 'off you go.' I drove the car just a few days after it finished the Endurance section of Formula Student at Silverstone, with the power cut back to 70 per cent and the ramp altered to make it more driveable in the torrential weather conditions.

Even in this hamstrung form, the car was pretty quick but, at the same time, incredibly easy to drive. With 30 per cent more power it would be super fast, in fact probably quicker than any of the previous FSAE-rules cars I've driven. So little noise and almost no vibration makes it all too easy to arrive at a corner way too fast and end up with armfuls of understeer to sort out - and the set up of the car certainly exacerbated this.

I also startled a few seagulls that were hanging out on the racing line, even being forced to swerve around one of them, who simply didn't hear me coming. I think the lack of fumes and noise make the cockpit a more pleasant place to be, meaning you can just concentrate on the fun element – and it's impossible not to smile as you are driving round.

"With a little development work this car could have real commercial success"

With a little development work this car, or a lightweight open-wheeler using its drivetrain, could have real commercial success, and that makes it very good indeed by FSAE standards. The only negative points I found were the lack of a rotary switch on the dash to allow you to adjust the power output, and I thought the styling was a little dowdy, but that's maybe just personal comment.

If the claims about recycling the batteries and their lifespan are correct, then UH12A could potentially be showing us the future of motor racing. That might sound a bit far fetched, but it really could. With no emissions and, more importantly, no noise pollution, more and better racing venues could be found and cars like this would go a long way to helping alter the public perception of motorsport as a noisy, dirty inconvenience.

Regression equation

Penske Racing Shocks' latest development offers a new way of overcoming the age-old conundrum of hydraulic damping, with benefits for both lap time and tyre wear

We ask an awful lot of the dampers on a racecar, or on any car come to that. We expect them to weigh nothing, cost less and yet perform a wholly contradictory set of critical functions that fundamentally control our racecars' handling and grip. And we expect all of this from a device based on a piston with holes in it, mounted on a shaft sliding to and fro in a sealed tube of fluid, the basic physical response of which is, in one sense, the opposite of what we really need.

Even the redoubtable Carroll Smith said in *Tune to Win*

BY SIMON MCBEATH

'Sometimes I think that I would have enjoyed racing more in the days of the friction shock. Since you couldn't do anything much to them or with them I would have spent a lot less time being confused.' And that was in the days when double adjustable dampers were as sophisticated as you could get. With top-of-the-range dampers now offering four-way adjustability, as well as a wide range of force vs piston velocity ('damping') curves, the potential for confusion would seem to have increased. But the impetus for multiple adjustability and non-linear damping curves goes back to a basic and somewhat unhelpful property of the hydraulic damper – that fundamentally it is sensitive to the velocity of the piston through the fluid. And this is exactly where Penske Racing Shocks' (PRS) latest development has been brought to bear.

Before we get to that, let's just briefly and simplistically re-visit why this velocity sensitivity works against us. When a wheel runs over a sharp bump or a kerb the damper piston moves at relatively high velocity (probably in excess of 15in/sec (381mm/sec) and possibly up to 40in/sec (1016mm/sec). When the car rolls or pitches it moves at much lower velocity (up to 5in/sec/127mm/sec might typically be seen during chassis movements). So when hitting a bump a very simple damper with a linear damping curve would exert a high damping force, but when rolling or pitching it would exert a much lower force. If the damper were then made to provide just the right level of damping for dealing with bumps, it would be grossly under-damped for the slow velocity movements like roll and pitch, and our racecar would handle very sloppily indeed.

Conversely, if the dampers were made to provide the correct roll and pitch damping, which provides the driver with a taut-feeling, responsive car that is generally much preferred, when hitting bumps the dampers would be far too stiff. This would provide not only a very harsh, choppy ride but also a loss of tyre compliance and grip, potential symptoms being wheel patter, lack of traction, premature sliding and wheel lock up as the dampers are unable to even out the vertical loadings and keep the tyres on the track surface.

Therefore, what we ideally want is a level of damping that provides responsive, confidence-inspiring handling, but which also enables the wheels to maintain optimum contact with the track. As our late and lamented friend and colleague, Allan Staniforth, put it in *Competition Car Suspension*, we are 'seeking the strongest control of suspension movement and spring forces that can be achieved without some unacceptable penalty'. Clearly, this is not easy to achieve.

DIGRESSIVE DAMPING

But it didn't actually require external adjustability to start to find better ways of addressing the problem. The first step was to provide 'blow offs' within the damper, generally in the form of shims that, above a certain pressure, would open up more holes in the piston and reduce the damping force

THE CURVES

Figure 1
Typical linear and digressive damping curve shapes

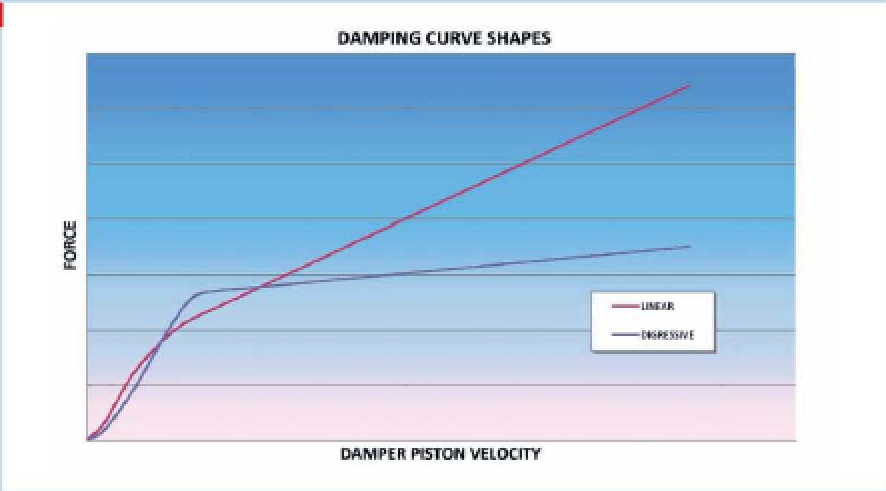
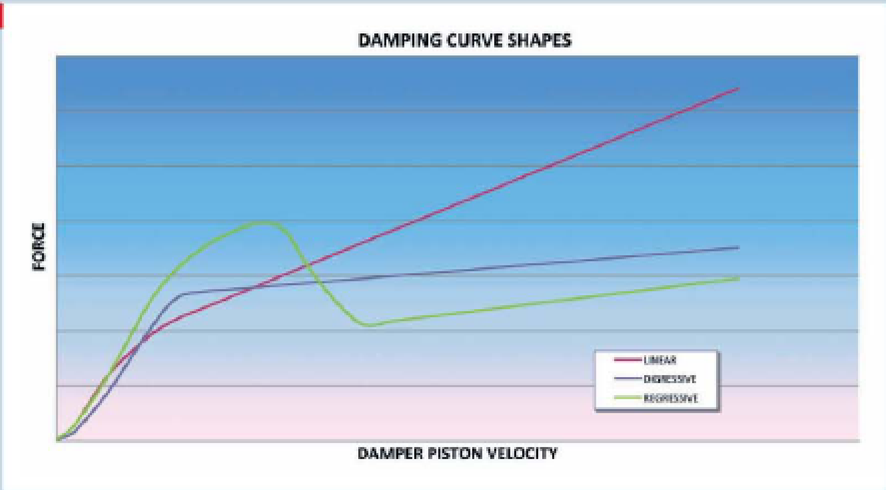


Figure 2
A regressive damping curve contrasts with the linear and digressive curves



at higher piston speeds. This provided what became known as a digressive damping curve in which the slope of the force vs velocity damping curve reduced above a certain piston speed (see figure 1). Changing the shims internally enabled alterations to the transition point at which the damping rate went from the low-speed to the high-speed rate. This then enabled higher damping rates to be run in the low-speed region to provide better chassis control without immediately compromising the ability to deal with track imperfections and kerbs, so digressive damping was a very useful step forward.

So far, no distinction has been made between bump (compression) damping and rebound (droop) damping, and the foregoing applies principally to compression in order to illustrate the general principle. We will take a look at rebound later.

Of course, the advent of independent adjustability of bump and rebound and then, in around 1990, of high-speed bump (then high-speed rebound) from low-speed damping brought with it even greater potential for confusion, but also the ability to tune the car much better to a given track. The basic problem though still remained – it wasn't possible to run the high-speed damping at low enough rates in many instances.

A STEP FORWARD

In *Racecar Engineering* V17N2 Andy Thorby described an approach from Koni, who Andy was working with during the 2006 season on the Formula 3 Euroseries Dallaras at Manor Motorsport. This was Koni's 'Frequency Selective Damper' (FSD) valve, which was able to distinguish between suspension movement events according to the rate (frequency) at which they happened. A long duration (low frequency) increase in damper pressure closed off the path to flow control shims, and instead forced fluid through ports with a high damping level. Short duration inputs meant that the pressure increase did not have time for this sequence to invoke, and instead the flow control shims were deflected, leading to low damping forces. It was stated that, once fine tuned, FSD improved grip on most tracks, especially where there were bumps and kerbs in critical places. So this appeared to be a way around the traditional conundrum, and a useful step forward from conventional digressive damping.

> "we needed our valve to be much more dynamic in its operation"

REGRESS TO PROGRESS

And so enter PRS's latest development, known as the 'regressive valve'. This uses a rather different principle (on which a patent is pending) to achieve a similar end, which is to provide lower damping rates at higher damper piston speeds (see figure 2). Indeed, the company says its new approach is 'about 180 degrees from the Koni FSD', adding provocatively that 'it was purely based on what a racecar needs.' Penske's Bill Gartner explains the background in full: 'When only linear damping curves were available, increasing the low-speed portion of the curve for good driver feedback meant drastic increases in mid to high-speed compression damping forces. So it was a case of balancing driver confidence against loss of grip or harshness over bumps. Digressive compression curves were likely developed to allow more aggressive low-speed compression damping to improve driver feel without the resulting [excessive] high-speed compression damping.

'However, high-speed damping levels with a digressive-style piston still could only be reduced down to the low-speed damping level because pressure and flow were linked. Therefore, low-speed damping levels could still only be increased to a point where the higher speed damping started to erode performance. For some applications a very flat digressive curve worked fine, but this didn't go far enough for some.

'The idea behind regressive damping began in Formula 1, where kerb strikes caused extremely high damper shaft velocities. During a kerbing event, the F1 teams want their suspension to allow the wheel to move quickly without upsetting the chassis, and to allow the driver to get back on the throttle immediately after hitting the corner apex. Regressive damping was meant to provide the requisite level of low and mid-speed compression damping for good driver feel and small bump absorption, but then cause drastic reductions in compression damping levels at higher shaft speeds when hitting kerbs.'

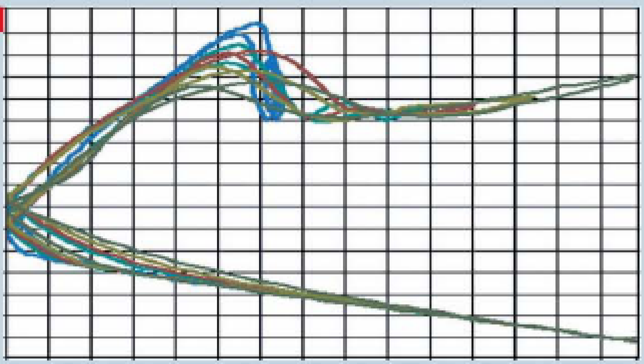
It seems that some years ago Penske's engineers devised some clever solutions to achieve regressive damping using complicated bypass tubes linked to the head valve pressure differential. 'These made for some complex and quite expensive dampers,' admitted Gartner. 'However, this was the heyday of spending in F1, when money was no object and complexity was almost revered!' he joked. And although regressive damping was a dream for more general racecar applications, the cost at the time was prohibitive, and kerb strike events not nearly so dramatic as in F1.

Fast forward to more recent times, and Gartner picks up the tale again: 'After yet another request by one of the F1 teams for regressive damping, our new regressive valve was devised. It uses variable pressure areas, and the concept is roughly similar to a latch valve in hydraulics, which locks itself open after a certain pressure is applied. However, we needed our valve to be much more dynamic in its operation. So we carefully matched the flow and pressure areas to create an extremely responsive valve that could not only blow completely open during the acceleration phase of a bump, but could also close during the deceleration phase toward the peak of a bump.

'After some testing we quickly realised that the rapid, stable response of the new valve could be useful for much more than kerb strikes! We started to test the valve with much lower velocity blow-off points, and much greater low-speed damping levels with good results. The increased low-speed damping provided the driver with such great feedback and chassis support that ultra-stiff springs

THE CURVES

Figure 3
Some actual regressive test data showing some of the available choice



were no longer necessary to control the vehicle. Softer rate springs were fitted, together with reductions in rebound damping, yielding instant gains in traction and decreased tyre wear.'

Gartner goes on to emphasise this latter point with a simple example of how the Penske regressive valve operates: 'If you can imagine a nicely shaped 'sine wave' bump [encountered in a cornering situation], when the tyre begins to climb the first part of the bump the low-speed compression damping helps to 'plant' the tyre, initially maintaining grip and providing the driver with good feedback.

At the middle of the ramp the highest [damper shaft] velocity occurs, and here the regressive valve blows off, dramatically reducing lateral tearing of the tyre surface. The accelerations leading to that area [of the curve], however, have a lot to do with how the valve responds through its frequency sensitivity.

In the next phase, the compression movement begins to decelerate towards the top of the bump. While other regressive arrangements may remain locked open at this point, our valve is responsive enough to close again and regain low-speed damping support. So a good regressive damper set up can feel like a very stiffly set up car with great support and responsiveness, but also allows the car to feel as though the tops of the bumps have been shaved off.'

LAT

Dario Franchitti's Ganassi Racing Dallara Indy Car finished third at Mid-Ohio fitted with Penske's regressive dampers

FREQUENCY SENSITIVITY

So has Penske achieved damping nirvana? Well, further claims are made that certainly make it sound like a significant step forward, including the fact that the regressive valve also seems to exhibit frequency response sensitivity, too. The Penske engineers have included a small bleed jet in the valve that controls how quickly the pressure across the valve can equalise. With velocity held constant, a longer duration, lower frequency sine stroke will allow the pressure to equalise across the valve, the valve does not open, and the low-speed [higher damping rate] support is maintained. However, a shorter duration, higher frequency event such as a square-edged bump sees pressure quickly build up on the valve – it opens very rapidly and high damping forces are 'never really felt by the driver'. This bleed jet is tuneable by adjusting the jet orifice size – a larger hole providing a slower reaction, while a small hole gives a fast-acting valve.

And finally, Penske has also found that the regressive set up can overcome other downsides of a traditional digressive arrangement. Apparently, linear damper pistons that have been dished to provide low-speed damping support, and which are seemingly preferred by drivers, can once again be used because it's the regressive valve that now provides the blow off at the transition to the high speed [lower] damping levels. 'Previously, one of the potential negatives of a digressive arrangement has always been how sharply the low-speed force builds (via orifice damping) and then how quickly the shims open to flatten off the compression damping curve.

'Using the regressive valve teams can once again revert to a dished linear piston and then simply use the regressive blow-off point to chop out the high-speed damping that they don't want.

'We have also developed a rebound regressive valve that can allow the same low-speed rebound control, along with drastically reduced mid- to high-speed damping. We find that some racing teams like to use low-speed rebound damping for chassis control in certain roll and heave situations. However, excessive high-speed rebound forces are never good for tyre grip, and the rebound regressive option helps to ease this compromise. Our regressive damping options are also being evaluated in Stock Car racing to help with the safety vs speed conundrum, where extreme levels of rebound damping are used to tie cars down to their bump rubbers at 200mph.'

> "the regressive valve seems to exhibit frequency response sensitivity, too"

Finding the right damper set up is never easy, and Gartner acknowledges that 'getting the right set up with regressive damping can be a bit challenging, finding the correct blow-off point and the correct level of low-speed damping. However, we are planning an externally adjustable version to help with development. We have also successfully developed regressive curves using our active damper system on a test rig, and plan to offer on track active services to help with development for teams as well.'

But the claims are bold: 'In test after test the regressive valve has allowed suspension tuners to unlock hidden performance in a wide range of racing categories.' And in case you don't believe the manufacturer's own claims, the following testimonial might just make you think: 'The PRS regressive valve opens up a new dimension in tuning opportunities by enabling a falling rate response. And PRS has provided us with useful guidance on the dynamic considerations involved when implementing the device. The regressive valve has certainly found a place in our damper tuning "tool chest".' The source of this quote? Target Chip Ganassi Racing's 'shock man', Mike Cicciarelli.

Time alone will tell if this is simply another step forward in damper development or a major breakthrough. Meantime, as well as the compression and rebound options already being worked on, one might imagine developments that incorporate multiple regressive valves that provide more than one transition point so that idealised damping levels can be provided at more than just two or three damper shaft speed ranges. Fanciful? Perhaps, but so would regressive damping have been when hydraulic dampers were first developed...

Go your own way

LAT

The BTCC has unilaterally adopted its New Generation regulations against the backdrop of a wider debate on cost cutting and Global Race Engines. Series director, Alan Gow, explains

BY GRAHAM JONES

The British Touring Car Championship has set the standard for modern national saloon car championships since plain-talking Australian, Alan Gow, took over the helm. Indeed, the BTCC's Super Touring regulations were adopted by many other countries and led to something of a golden age for this form of tin-top racing throughout the 1990s. In more recent times, the series has adopted Super 2000-based rules (as used in the FIA's World Touring Car Championship) and, although continuing to draw large crowds to the circuits and enjoying regular television exposure, Gow felt it essential to define, with clarity and at the earliest feasible date, the future technical direction of the BTCC.

As head of the UK's Motor Sport Association (MSA), he was also well aware that there was considerable debate taking place within FIA circles regarding the possible development of a so-called Global Race Engine (see *Racecar Engineering* V19N8) that could be used, with adaptation, across a number of different motorsport disciplines. Current thinking suggests this

CHANGES FOR 2011

The New Generation Touring Car (NGTC) rules, which come into force in 2011, display the sort of pragmatic approach and refusal to 'follow the herd' that has characterised the BTCC in the modern era. The highlights are as follows:

- Front-wheel drive
- Engines to be standard specification, production-based, 2.0-litre, turbocharged, four-cylinder petrol units producing approximately 300bhp with a 7000rpm rev limit, 0.8bar boost and inlet restrictor
- A TOCA (unbranded) NGTC engine will be commissioned and available to those teams not wishing to undertake their own individual engine development programme
- Standard six-speed sequential, semi-automatic gearbox
- Minimum length of 4.4m
- Standardised width of 1875mm
- Two, three, four or five-door variants of a particular model may be used, providing it shares the same basic silhouette and dimensions as the four / five-door saloon version
- Standard subframes with fully adjustable front and rear suspension
- Larger wheel (10 x 18in) and tyre combination
- Common components to be used, including ECU, gearbox, brakes, hubs, steering rack and fuel tank

> "we have achieved a massive cost reduction for teams to compete in the BTCC"
>
> **ALAN GOW, BTCC SERIES DIRECTOR**


LAT

could be a 1.6-litre unit, capable of producing up to 300bhp in turbocharged form, with initial applications likely to be in Formula 3, WTCC and the World Rally Championship, but so far the manufacturers differ in their views concerning whether the GRE should be a production-based or motorsport-specific unit.

THE COST EQUATION

Another major issue currently occupying the FIA's collective thoughts regarding motorsport is cost or, more specifically, reducing the cost of competing, and this was also very much on Gow's mind when considering the future direction of the BTCC. In the 1990s, there was a high level of manufacturer / importer participation, with Ford, Vauxhall, BMW, Audi, Renault, Nissan, Volvo and Alfa Romeo, among others, all competing at one time or another, with the result that money poured into the series. In recent years, however, professionally run privateer teams have provided the majority of the entries, and that trend looks set to continue for the foreseeable future, given the major hit taken by the motor industry in the current recession.

As Formula 1 has clearly reminded us this year, vehicle manufacturers come and go from motorsport according to their own agendas, which nearly always tend to be dictated by commercial and marketing considerations rather than sporting considerations. Strategically then, Gow's aims with the new regulations were to slash the cost of building / buying and maintaining cars, while increasing performance and safety, reducing CO_2 emissions and ensuring greater equality of performance. While doing all this, it also seems clear he wanted to try and re-discover some of that intangible 'magic' from the Super Touring era.

In order to accomplish all of this, in October 2008, he instigated the setting up of two technical working groups – one for engines and one for chassis – to consider the basis for new BTCC technical regulations. Under the direction of TOCA technical manager, Peter Riches, and working closely with existing teams, the groups progressively hammered out a set of rules that met all the requirements Gow had laid down. By June of this year, the new regulations had been drafted, unanimously approved by the championship teams and formally announced.

CLEAR DIRECTION

Summing up the new regulations, Gow says, 'Our teams now have clear direction on what the future BTCC car will be, while – very importantly – protecting the investment in the S2000 cars they currently run up until 2013.

'Of huge significance is the fact we have now achieved a massive cost reduction for teams to compete in the BTCC, with car / engine build and running costs that will be some 50 per cent below the present level. The fact that most teams will be able to undertake a very serious BTCC effort for around half the cost they have today also makes the dream of competing in the BTCC much more of a reality for many new teams and drivers.

'The BTCC's great success

> "car / engine build and running costs some 50 per cent below the present level"

CHANGES FOR 2011 CONTD.

- Integrated front aerodynamics, incorporating radiators, cooling ducts, a partial flat floor to a specified design parameter, specified rear wing profile and size
- Each model to be wind tunnel tested to ensure similar aero performance
- Increased driver safety
- Stronger, more robust components with full at-event parts support
- Production bodyshell with a standardised rollcage design and standardised engine location
- Car design, development and build costs to be reduced by 50 per cent from current level, with an achievable target price of £100,000 per car 'ready to race', plus engine
- New engines to cost around £15,000 (after initial development costs). Engines to last a full season between rebuilds, with a rebuild cost of approximately £8000
- Mandated turbo, wastegate, intercooler, injectors and ECU to reduce costs and opportunities for technical infringements
- A policy of equivalence in performance between the current Super 2000 and 'Next Generation' cars will be maintained until 2013, to provide asset protection for the S2000 cars and parity of competition throughout that period
- Stability of the new technical regulations will be maintained for at least five years, with review in 2016

has always been through its incredibly close and exciting racing. These new regulations will absolutely guarantee that those virtues solidly remain at the very core of the BTCC.'

From a technical standpoint, one of the more interesting aspects of the NGTC regulation is TOCA's decision to go with a 2.0-litre engine capacity rather than 1.6-litre, which currently appears to be the favoured approach in FIA circles for the basis of the proposed new Global Race Engine.

DIFFERENT APPROACH

'We've achieved the same result [as a 1.6-litre turbo engine], but in a different, much more cost-effective way,' says Gow. 'They want a 300bhp, four-cylinder, turbocharged Touring Car engine. We wanted a 300bhp, four-cylinder, turbocharged engine, but ours is going to cost a third of the price. We've just gone about it in a totally different way from how they're approaching it, and arrived at a solution that is going to be much easier for the teams, not only to embark on their own engine design and development programmes, but also to contain maintenance and spares costs.'

Speaking of the FIA working group studying possible approaches to the GRE, Peter Riches adds, 'They're talking of what the cost of a block should be and what an engine should cost, but what they're not saying is what the development cost is behind it. We looked at development costs and said we think developing a 2.0-litre with a turbo is a lot cheaper than trying to do the other things.

'There's a strong belief from a lot of manufacturers that to do the global engine successfully, you will have to have a motorsport block and cylinder head, which moves you away from the concept of taking a production-based engine into racing. To achieve 300bhp out of a 1.6-litre turbo and make it last all season... there are fears at the moment about heads and blocks cracking, but it's early days yet.

'The fact is, we need to change as quickly as [the WTCC] is going to change, but we don't have six manufacturers saying they want to participate.'

Summing up, Gow says, 'We just went about it in a much more simplistic way. We said, "These are the broad outlines of what we want for our new car in terms of size, cost and how it should look," and the working groups came up with the details. In terms of the engine formula, they came up with this, which is one of the most sensible ideas I've heard for years. It provides the cheapest, most cost-effective engine solution for the next five years.

> “the cheapest, cost-effective engine solution for the next five years”

EQUAL PERFORMANCE

'We get a car that has at least equal performance to the current cars – if not better – because 300bhp is slightly above what the engines are producing at the moment, and you can future-proof it by increasing the power output, so you're getting a car that is quicker than what we had before, much cheaper and much easier for the teams to maintain. It's a bit of a no-brainer really.'

Aside from the decision to go with a 2.0-litre turbocharged engine, the other point in the NGTC regulations to raise a few eyebrows is the apparent writing out of rear-wheel drive cars. Gow, however, is quick to clarify

LAT

With wider wheels and a new aero package, the Next Generation cars could look more like the 1990's Super Tourers

this point: 'We haven't actually ruled out rear-wheel drive, we just haven't written it in yet. The reason we haven't is because we haven't received any firm commitment from manufacturers of rear-wheel drive cars that they would support a team or teams in the championship. Now if, for example, BMW came to us and said, "okay, we would like to help any team that wants to race a BMW [in the BTCC] by doing an engine and all the necessary bits for them," then we would look at it. All we're saying is that there's no point in writing [rear-wheel drive cars] into the regulations and putting tenders out for certain components – notably the transmission – unless someone is actually going to run them. That would be unfair.'

NEW LOOK

Finally, the physical appearance of the New Generation Touring Cars will be different, with the mandated 4.4m minimum length suggesting the cars will be physically larger than several of the models currently competing in the BTCC. Did this indicate a desire to get back to cars that look more like the Super Tourers of the 1990s?

'Well, when we say "bigger" cars, what we've done is just move away from encouraging people to use too small a car,' explains Gow. 'A Touring Car is a Touring Car – it's generally thought of as a four-door saloon. I think that's pretty much anyone's definition of a Touring Car. All our [new] regulations do is essentially knock out the little cars, like the current Honda Civic, but it doesn't move the [choice of car] to the next segment up.'

Gow also points out that the new minimum length simply reflects the fact that the current segment cars appropriate to the BTCC are larger than they once were. 'They all grow,' he observes, 'and, of course, don't forget that 4.4m is the minimum length – you don't *have* to go bigger than that. You wouldn't have to use a Vauxhall Insignia, for example, unless you specifically wanted to. An Astra would fit within the mandated dimensions. It's also worth bearing in mind that as long as the profile of the car is the same, then it doesn't matter how many doors it has.'

In terms of appearance, then, it seems clear the BTCC is heading back more to the Super Touring look of the 1990s – a move that is likely to meet with approval from a number of quarters. 'They probably won't look that much different from the old Super Touring cars,' observes Peter Riches. 'They'll have a deeper front spoiler, plus splitter, similar wheels to the STs, but wider at 10 18in and, instead of some of the fairly nasty wing extensions that often cover only half the wheel and tyre at present, the wings themselves will be widened and then drop down to cover the entire wheel.'

> **"Bigger, faster, cleaner, safer, slicker-looking and much cheaper"**

Gow adds with a smile, 'If you look back at the ST cars, I know the profile of the wings and some of the bodywork was often the subject of much dispute, but the way it all blended in looked good. That's what we want to get back.'

Bigger, faster, cleaner, safer, slicker-looking and much cheaper – that appears to be the basis for the BTCC racecar of the future. It's a difficult concept to argue with, but will it be the formula to carry the series' popularity back to the levels it enjoyed in the heady days of Super Touring, and will TOCA's clearly framed new technical regulations lead to other national championships adopting similar rules?

'They weren't designed for that, but if other countries do, they do,' replies Gow. 'Our job is to look after our own series rather than concern ourselves with what we think might help the WTCC, or any other series. The BTCC is the most important thing for us.'

LAT

Packed grids and close racing are BTCC hallmarks. With a 50 per cent reduction in costs and a number of standardised parts, its future is looking bright

Audacious engineering

LAT

Active suspension was one of the most exciting developments in F1. Dave Williams was the man responsible and recalls how it came about

BY CHARLES ARMSTRONG-WILSON

Team Lotus' experiments with active suspension during the 1980s were probably the most audacious take on racecar suspension ever. For a few years, springs, dampers and anti-roll bars were consigned to the scrap bin and replaced with virtual versions existing only in computer software and mimicked by hydraulic actuators. It was a radical approach but it was no flight of fancy and was a pragmatic attempt at tackling real-world problems. Engineering consultant Dave Williams was in the thick of it and, a quarter of a century later, his recollections offer a privileged insight into a radical venture.

Team Lotus had called him in as a consultant during 1976, following work with Cranfield University on fitting sensors to aerobatic aircraft. The small, light data recording equipment he had been using was equally suited to a racecar and the team wanted to better understand what was happening to its grand prix cars at speed.

'That gave us an insight into many things that were happening with the car that at the time we hadn't any idea about,' recalls Williams. 'For instance, with the crossply Goodyears they were using at the time, going down the straight, 80 per cent of the torque was taken by one tyre.' Tolerance in their manufacture meant that when spinning at racing speeds, the centrifugal force caused them to grow at different rates. Inevitably, the larger tyre was doing most of the work and the smaller one was not developing anything like the traction it was capable of.

'Mainly we were looking at pressures associated with downforce. I slowly became sucked into the engineering problems they had, which culminated in the Lotus 80.' This was Lotus' ultimate ground-effect car, based on what the team had learned from its championship winning Type 79. It was so dedicated to the concept of generating downforce from the airflow under the car that it eschewed conventional wings altogether. However, once the car started testing it quickly became apparent that all was not well when the prototype sprouted wings on its nose.

ANY CORNER... ANY SPEED

'I did a bit of work to try and understand what was happening with that car, and essentially it porpoised,' recalls Williams. 'Peter [Wright] said it was a car that would go round any corner at any speed, which was probably true, but it would also porpoise at anything above 80mph. It was an aerolastic problem. It was not linear in the sense that, as speed increased, the space beneath the venturis decreased until the airflow stalled. It would go at a frequency at which they still go, which is six to seven hertz.

'We discussed various options. We tried putting rigid links in place of the suspension and putting dynamic absorbers on the uprights – functionally, the same thing that Renault put inside the tub.' However, this was in 1980, but they didn't pursue it because, in Williams' view, they put them in the wrong place. 'We mounted depleted uranium weights in the uprights, which was the right place to control the car, but the wrong place because it interfered with the driver's perception of what the car was doing.' He found the drivers complaining that they couldn't feel what was going on at the wheel. In contrast, he noted that 'putting it in the sprung mass doesn't work quite as well but it does the job.'

Williams wrestled with the problem before his eureka moment. 'It occurred to me that really the ground-effect car needed a suspension that would react to road inputs, but not react to changes in aerodynamic downforce. The only way you could achieve that was with an irreversible suspension.'

He put it to Wright, but he felt it would be too complex and the team was already working on its twin-chassis car, the type 88, in an attempt to separate the aerodynamic loads from the suspension within the letter of the rules. Unfortunately, after building and proving the concept, the 88 was thrown out by the FIA, forcing the team into a re-think. 'When that was black flagged, Peter came and said, "What about active suspension?"' remembers Williams.

With the basic concept in his head, did he have an idea of how to go about it, we asked? 'Vaguely, yes, but not in detail. Colin Chapman wanted to do it directly on a Formula 1 car. I said no. It went as far as Peter going away, then he came back a few

WHAT IS ACTIVE SUSPENSION?

LAT

In 1993, it transpires Lotus was struggling with aeration of the hydraulic fluid in the open circuit system

'Active suspension' is one of those terms that just sounds right, and so has been loosely applied to a variety of suspension systems. In its simplest form, it is a slow self-levelling system, as employed so successfully by Citröen, and others. It basically levels the vehicle as payload is changed, but does not respond to inertial, aerodynamic or road-induced loads. Its response time is several seconds. Speed up the system to respond in around 0.2 seconds, and so it can react to inertial loads – acceleration, braking, and cornering – and to changes in aerodynamic lift, and it becomes useful in a racecar.

This type forms the basis of all the systems used in racing, *other* than the Lotus system. The difference with the Lotus system is that it responds over five times faster, and so can take control of road-induced loads as well.

While a passive suspension absorbs and returns energy to the sprung and unsprung masses using the spring, and dissipates some of it in the damper, an active suspension requires an external energy input to allow it to deviate away from the conventional spring / damper laws by allowing it to extend against an increasing load – as described in the main article.

In racing, the first and foremost benefit of an active suspension (and the quality for which it was banned in 1993) is to take control of the attitude of the car relative to the ground, in doing so achieving a measure of control of the ground effect-influenced part of the downforce. The additional, unique and relevant-to-road-car benefit of the Lotus system is that it takes control of the tyre contact patch forces over road-induced perturbations. In racing, this controls tyre temperatures, degradation and wear. When it raced, it was this feature that was the key to its performance: when tyres were overworked, the Lotus benefited by being easier on them. However, when it was difficult to get the tyres up to temperature, it suffered.

> "[the] benefit is to take control of the attitude of the car relative to the ground"

In 1993, Lotus was struggling with achieving full control and it is now known that the problem was aeration of the hydraulic fluid in the open-circuit system, putting an additional and unwanted spring into the control system. In the first few laps of the day, the car was sensational, but deteriorated the more it ran. Current F1 cars all run aircraft-style, closed-circuit hydraulic systems, and this would have cured the problem. The fascinating question is, where would we be now if active suspension had not been banned?

Peter Wright

Ayrton Senna took the Lotus active suspension technology to its first win when he won the '87 Monaco Grand Prix

LAT

days later and said, "Alright then, what do you want to do?" So, we chose an Esprit out of the parking lot to get things going. That was quite useful and also quite difficult to work with for various reasons. But over the course of three months it went from being a total nail to something that was actually quicker than a standard Esprit, much to my surprise and everybody else's.'

Williams has clear memories of what the biggest challenge was. 'It was developing the control algorithms,' he notes. 'There was no physical linking. It was all done virtually via the algorithms. The hardware was pretty straightforward. At the time it was an analogue system with potentiometers inside the cockpit you could change the loop gains with. We had four load cells, one on each corner, accelerometers attached to the unsprung masses, accelerometers attached to the sprung mass – importantly in longitudinal and lateral directions – and road speed and yaw rate. There were 24 transducers only, some of which were directly involved.

'I thought, since I had been modelling vehicle behaviour for a while, it would be fun, rather than model springs and dampers on a car, it would be better to model modes of springs. That's what we did and that's the way it stayed.

'Also it had the concept of imitating a heave spring and damper, and a pitch spring and damper in roll and eventually warp, all of which we could control independently. So you could have a car that would heave and pitch at the same natural frequency or you could reverse it. You could do things that you couldn't achieve with a conventional passive set up. It became very easy to control, for instance, the ride and attitude of the car. You could make it bank into a corner and do strange things like that.'

> "You could do things that you couldn't achieve with a conventional passive set up"

Once the concept had been developed and proved on road cars it was time to test it out on the racecars. 'We threw it at our race drivers first, [Nigel] Mansell and [Elio] De Angelis. They were both quite impressed by it. Even though by that time ground effect had been limited with the skirts removed. It first ran on the morning Colin Chapman died. We went testing at several places. It worked and it ran the first two races of the year.'

Things in F1 and at the Lotus base at Hethel then started to change. On the track, turbo engines were starting to come good in the wake of Renault's initiative to try them in the previous decade. Team Lotus had secured a supply of the French manufacturer's engines for the 1983 season and was evaluating their potential. 'We went to the first test with one Renault 1.5-litre turbo and two Cosworth DFV cars, one passive and one active. The Renault produced about 50 per cent more power than the DFV and, at the end of the straight, was about 40mph quicker. There was nothing you could do with the suspension that could keep up with that. Anyway, Renault refused to allow us to attach a hydraulic pump to the camshaft, so there was no future for active at the time.

'But the two races stimulated the interest of GM who visited, and so started a period of several years where we built research cars for several manufacturers. I suppose we built 30 or 40 cars for different manufacturers. That was quite instructive. We started to understand the interaction between the tyre and the vehicle. We received a lot of interest from Michelin in particular, who ordered a Volvo road car with active.' This was the era when Lotus became an engineering consultancy to the motor industry following on from its ill-fated involvement with DeLorean.

However, the team took active suspension back to F1 again in 1987 once the

ACTIVE TIMELINE

1981
FISA introduces a rule that means all cars must have 6cm ground clearance. Lotus responds with the 88, but it is banned soon after.

1983
Lotus uses the first active system on the 92. At Long Beach Nigel Mansell gives active suspension its competition debut.

1986
Williams tests its first re-active suspension system.

1987
Lotus commits to running the system for the full season.

Senna gives active suspension its first victory at Monaco.

1993
Active suspension banned for the 1994 season.

turbocharged power battle had stabilised once more. This time Wright envisaged a full active suspension programme for the cars and the timing was right.

'That was an extremely interesting year because we had a good grasp of the system and what its full potential was. Also Lotus happened to have an extremely good driver driving for them.' Williams cites Ayrton Senna as a big help when trying to squeeze the advantage out of what was a very complex system.

'It did make a car that had quite a few problems into a raceable car.' But, for a while, the advantages didn't appear to be materialising and nobody seemed to know why. 'We didn't progress as fast as other people and it wasn't until Mexico when we did a cold tyre start, because tyre heaters were prohibited there, that we discovered why. It was because we had reduced the loads transmitted through the tyres so much that I think it took around 12 laps to get them up to temperature. Everybody was up to temperature after two laps. He [Senna] went from second to 14th before he started to get to grips. And that was what we had done almost without realising it.'

Knowing what the problem was, a solution should have been straightforward, but the team was wary of transgressing the rules. 'We did it the honest way, which kind of took away the advantages of active suspension and effectively made it back into a conventional suspension.' But Williams wanted to do it a different way. 'When the car is on the straight and not turning, I wanted to vibrate the tyres to put vertical load variation into them and turn it off whenever the car was cornering. But there was, and still is, a rule that says aerodynamic surfaces cannot be moved, and it might have been argued that we were doing it to control aero. If somebody attains a significant advantage, there's a tendency to ban it and work out how to [enforce it] later.'

By now, Williams' career was taking him in a different direction. 'I had to move away after 1987/'88, and Lotus by that time were up and flying with it.' Lotus Engineering was now a fully fledged consultancy helping

LAT

When the twin chassis Lotus 88 was banned, Peter Wright suggested the use of active suspension

major motor manufacturers evaluate active suspension for road cars. Also Team Lotus had changed its approach to active and was going in a similar direction to the other teams. 'It was based on their interpretation of what everybody else was doing. There was a big difference between the system Lotus was using and the ride height control everybody else was using.'

The systems other teams were running didn't offer very sophisticated suspension and to achieve ride height control didn't require much energy input. However, the Lotus system provided very sophisticated suspension response for relatively little power consumption, whereas ride height control consumed a lot of energy.'

However, this was not the last of fully active suspension at Team Lotus. In 1992, with Chris Murphy heading the design team, it had recovered some consistent performance. In the face of constrained budgets, Wright decided to re-visit the active suspension concept in pursuit of a competitive edge. So, for 1993, Team Lotus fielded a fully active car and it did indeed give them more performance. Johnny Herbert scored three fourth places but could only manage ninth in the championship and the team finished equal sixth in the Constructors' Championship.

> "its promise of performance was compromised by the challenges of running"

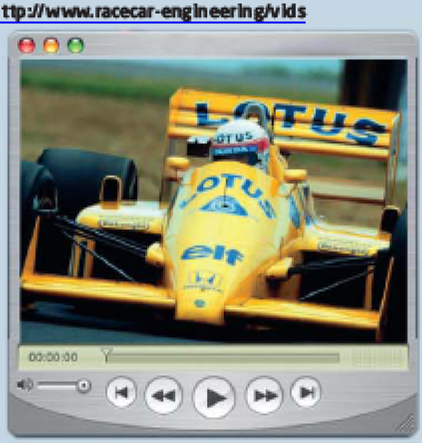
Unfortunately, its promise of performance was compromised by the challenges of running the car. Murphy recalls: 'It was a very, very complex car. In truth, there were only a few people in the R&D department who really knew how to run it.' Time that should have been spent refining the conventional parts for the car was often consumed by the suspension and making it work. 'It wasn't a bad car but it was difficult because reliability was difficult,' he says.

Once mastered, though, the system definitely gave advantages and the trials and tribulations of the 1993 season were set to pay dividends. In the following years, the team would be able to operate a fully active car, putting them ahead of the competition who would be forced to follow. Sadly, that was the last year of active systems in F1 as the FIA sought to ban all such technologies in an effort to hand more control back to the drivers. At a stroke, all the time and money invested in developing the race version of the system had been declared fruitless.

By now, Williams' association with the project had finished and the end of what he regards as a very exciting era in his career and in suspension development had come to an end. Active suspension on F1 cars is still outlawed today, while a motor manufacturer has yet to put into series production a car with fully active suspension.

WATCH THIS

Demonstration of the active suspension system on a F1 Lotus 99T
Go to **http://www.racecar-engineering/vids**



The anti controversy response

LAT

In our final instalment - at least for the moment – on anti effects, Danny Nowlan clarifies his views on taking a force-based approach to suspension geometry

BY DANNY NOWLAN

My article in *Racecar Engineering* V19N3 about force-based anti-dive and anti-squat has certainly sparked some lively debate. In my original article I invited readers to prove me wrong and I have no regrets that I made that invitation. I have long been of the view that a good, robust technical discussion will always get to the bottom of an issue, regardless of whether you were right or wrong. It also forces you not to take anything for granted. I should also add that just because I author technical articles doesn't necessarily mean I'll always get it right. One of the biggest traps I see in motorsport is someone establishing themselves as a successful engineer, getting a few results then everyone automatically assuming they are God and immune from criticism. This is why I always present my thinking on an issue and then present a thorough proof so readers can draw their own conclusions.

However, as a result of my article in V19N3, there have been a number of issues that need clarification. Furthermore, as result of the debate that has ensued, I actually believe it's an ideal time to get some things out in the air so we can move forward on this issue. Just so that we are crystal clear on what we are discussing, let me return to the thrust of my original article.

- Structurally, the forces do go through the axle line.
- However, in terms of applying forces and moments about the c of g in acceleration and braking the applied longitudinal forces can be visualised as acting on the ground.
- My big problem was that a lot of the traditional literature didn't supply a clear proof of where their numbers came from and what the mechanism driving it was. In particular, in acceleration, it was a case of 'here are the numbers and off you go'.
- It was from this basis that the concept of the pitch centre was formed. The pitch centre was defined as the moment arm from the c of g to the applied longitudinal forces. We went to great lengths to calculate it and a proof of where it came from.

Indeed, I would actually argue that anti-dive and anti-squat is one of the most poorly documented and worst explained concepts I've ever come across. It's why I've written an article about it because, quite frankly, it shouldn't be this hard.

Before I address this, let me again state the motivation for the force-based anti-dive and anti-squat articles. That article was years in the making because so many of my customers have come to me and asked 'What do we do about anti-dive and anti-squat?' Many of them have read the traditional theories and approaches, and when doing their own calculations could never quite marry up what they saw in data to what they had calculated by hand. This created much head scratching on both sides of the fence and was the trigger for me considering force-based anti-dive and anti-squat.

The biggest objection raised to my article concerns my assumption that all vehicle motion is as a direct result of all forces and moments about the c of g, and the free body diagrams that came as a result of this. The basis of this objection is that because the car is connected to the ground, our supposed physics textbooks don't apply. Nice idea, but there is one small problem. This is in direct violation of Newton's second law of motion:

$$m \cdot a = \sum_{i=1}^{n} F_i \qquad (1)$$

What this law states is that the mass times the acceleration of a body is the sum of all the forces acting it. The extension of this to angular motion is that the sum of the moments about a particular axis gives the rotational acceleration multiplied by the relevant inertia. There are no exceptions to this. None.

Rather, what is going on here is the forces and moments being acted on at the c of g rise as a direct result of the forces being applied by the springs and the suspension linkages as a result of that said car interacting with the ground. To illustrate this, let me present to you the bicycle model of a racecar. An SAE paper by Floyd and Law[4] presented this very clearly. Their formulation is shown below in figure 1. Just so the reader knows, I am taking the liberty of reversing the sign conventions. That's okay, though, as the results work out to be exactly the same. So we are crystal clear, the variables here are as follows:

- z = movement of the chassis down (m)
- _ = pitch angle of the chassis (radians)
- xtf = front tyre displacement (m)
- xtr = rear tyre displacement (m)
- kf = front spring rate (N/m)
- cf = front damper rate (N/m/s)
- ktf = front tyre spring rate (N/m)
- kr = rear spring rate (N/m)
- cr = rear damper rate (N/m/s)
- ktr = rear tyre spring rate (N/m)
- m = sprung weight mass (kg)
- Iy = sprung weight inertia along the y axis (kgm2)
- mtf = front tyre mass (kg)
- mtr = rear tyre mass (kg)
- a = distance from front axle to c of g (m)
- b = distance from the rear axle to the c of g (m)

VISUALISING THE MATHS

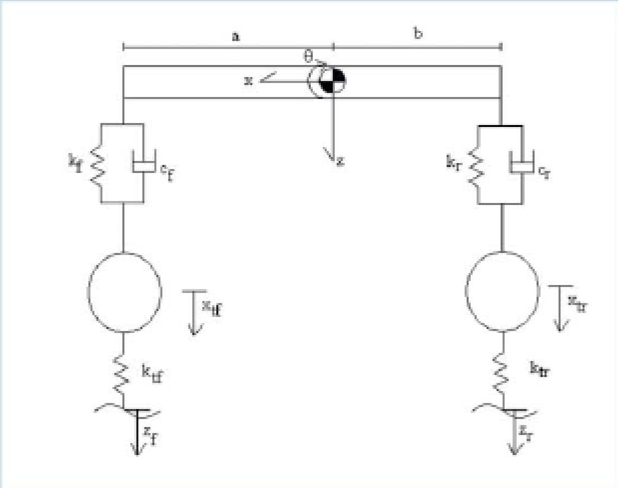


Figure 1
Half car model for bumps

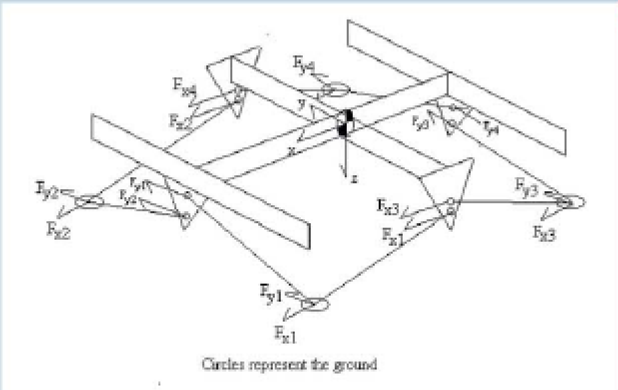


Figure 2
Visualisation of how the suspension geometry forces are applied to the chassis

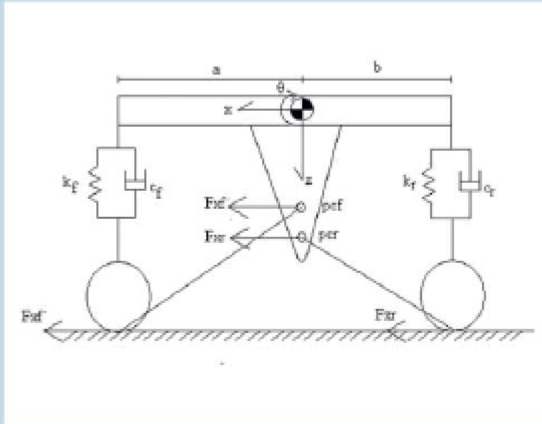


Figure 3
Bicycle visualisation of the pitch centres

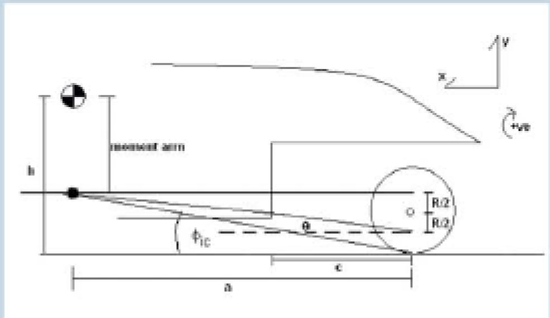


Figure 4
Bicycle visualisation of the pitch centres

By taking free body diagrams of the sprung mass and front and rear tyres it can be shown that,

$$m \cdot \ddot{z} = m \cdot g - k_f(z - a\cdot\theta - x_{tf}) - c_f(\dot{z} - a\cdot\dot{\theta} - \dot{x}_{tf}) - k_r(z + b\cdot\theta - x_{tr}) - c_f(\dot{z} + b\cdot\dot{\theta} - \dot{x}_{tr})$$
$$I_y \cdot \ddot{\theta} = a\cdot\left(k_f(z - a\cdot\theta - x_{tf}) + c_f(\dot{z} - a\cdot\dot{\theta} - \dot{x}_{tf})\right) - b\cdot\left(k_r(z + b\cdot\theta - x_{tr}) + c_f(\dot{z} + b\cdot\dot{\theta} - \dot{x}_{tr})\right)$$
$$m_{tf} \cdot \ddot{x}_{tf} = k_f(z - a\cdot\theta - x_{tf}) + c_f(\dot{z} - a\cdot\dot{\theta} - \dot{x}_{tf}) + m_{tf}g - k_{tf}(x_{tf} - z_{bf})$$
$$m_{tf} \cdot \ddot{x}_{tr} = k_r(z - a\cdot\theta - x_{tf}) + c_r(\dot{z} - a\cdot\dot{\theta} - \dot{x}_{tf}) + m_{tr}g - k_{tr}(x_{tr} - z_{br}) \quad (2)$$

Floyd and Law[4] provide a very good explanation of the derivation of this and I would refer the reader to that paper. I have deliberately left the mass and inertia terms in to show you where everything is coming from. As you can see, when we hit a bump this provides a force to the front or rear tyre. This, in turn, generates a change in the tyre displacement, which in turn changes the relevant spring movement. It is this key interaction that is how the sprung mass interacts with the ground.

As can be seen, we don't have to put in any fancy exceptions because by using some basic analysis we have described very well what is going on with the tyres and sprung mass. Furthermore, the formulation illustrated is the bedrock of every vehicle simulation program I know. This is both for road and racecar applications. If I'm wrong, fair enough. However, try telling that one to the engineers at Volkswagen, Peugeot and the like. You'd be lucky if you made it past the front door!

So, given that we have illustrated how vehicle motion about the sprung mass and tyres can be quantified, how do we go about quantifying this for suspension geometry and the forces this acts on the c of g? Mitchell's[5] approach to force-based roll centres showed a very powerful way of visualising this, and to clarify my approach from my first article let me illustrate how suspension geometry forces are applied to the sprung mass and the tyres. All the forces being reacted by the suspension geometry can be visualised as acting through the force-based roll centre (laterally) and the force-based pitch centre (longitudinally). First though, let me clarify this mathematically. In roll we have,

$$M_{x1} = F_{y1}\cdot(h - frc_1)$$
$$M_{x2} = F_{y2}\cdot(h - frc_2)$$
$$M_{x3} = F_{y3}\cdot(h - frc_3)$$
$$M_{x4} = F_{y4}\cdot(h - frc_4) \quad (3)$$

What the force-based roll centre represents is the length of the lever arm from the applied lateral force to the c of g. This, mathematically, is the essence of force application points. This is why I've termed it frc1 to frc4, which is an acronym for force-based roll centre. Similarly, in pitch we can state,

$$M_{y1} = F_{x1}\cdot(h - fpc_1)$$
$$M_{y2} = F_{x2}\cdot(h - fpc_2)$$
$$M_{y3} = F_{x3}\cdot(h - fpc_3) \quad (4)$$
$$M_{y4} = F_{x4}\cdot(h - fpc_4)$$

That is the pitching moment of each individual longitudinal force that can be viewed as a force acting under the c of g with a moment arm that is the difference between the c of g height and the force-based pitch centre. This incorporates all moment influences due to both applied forces and torques. This is the definition of force-based pitch centre. This is why I've referred to them as the fpc1 through to fpc4. Just so there is no confusion, my tyre numbering convention is 1 is the front left tyre, 2 is the front right tyre, 3 is the rear left tyre and 4 is the rear right tyre. This is shown graphically in figure 2.

Forgive me if figure 2 is a bit messy, but I wanted to show how all the forces act to pitch and roll the chassis. Effectively, what I'm showing is the location of all the force-based roll and pitch centres. The only thing I haven't shown is Fx4, and only because it was slightly obscured by the rest of the picture. To further clarify, let me show you this in bicycle form, as shown in figure 3.

Just so we are clear, for ease of illustration I've assumed symmetry, so pcf = fpc1 = fpc2 and pcr = fpc3 = fpc4. The astute reader will quickly see this is easily extended for an asymmetric case.

In each case I have shown the force-based roll and pitch centre points directly underneath the c of g, with a line connecting it to the contact patch. I have done this because it is the slope of this line that actually dictates the anti forces. These anti forces are dictated by the tan value of that angle multiplied by the applied force. Others refer to this line as dx/dy for the lateral case and dx/dz for the longitudinal case.

This is the power of the force-based approach: In one fell swoop we can characterise how the forces pitch and roll the chassis and how these individual forces supply loads direct to the tyres (or, in old speak, jacking forces). For convenience, I sometimes express the pitch centre as a fraction of the c of g height. Even though some define per cent anti-dive and anti-squat as load on the suspension/total weight transfer, I actually prefer to refer to my anti-dive numbers as a percentage of the c of g height because it gives me an instant picture of what the moments about the c of g are doing. For clarity, let me define this as the anti-dive anti-squat factor.

$$ads\_fact_i = 100 * \frac{fpc_i}{h_{cg}} \quad (5)$$

It has been alleged by some that this is a very odd way of measuring anti-squat and dive, but I am not the only one to visualise suspension geometry forces using a force-based approach. Blundell and Harty's[6] visualisation of suspension geometry is identical to what has just been presented to the reader. Indeed, their definition of anti-dive and anti-squat is identical to equation (5). I should also add, we constructed this approach entirely independently.

Our job now is to calculate these lines and then show how this can come to pass. The situation in roll I will leave for another time as it's almost an article within itself. However, let's review the situation in pitch. Refreshing the reader's memory, the pitch centre can be found by the approach shown in figure 4.

> **"I am not the only one to visualise suspension geometry forces using a force-based approach"**

So the pitch centre is found by resolving the instant centre location and finding its gradient to the contact patch. We will refer to this angle as ic. Then the pitch centre location is given by,

pcf =(distance of contact patch to c of g)*tan(ic) (6)

The force transmitted straight through the tyres is

L = Fx*pcf/(distance of contact patch to c of g) (7)

There is an addendum I'm going to add to this, but first let me discuss a case study where we shall compare the force-based pitch centre to the more traditional methods.

CASE STUDY – V8 SUPERCAR

The case study I'm going to present is tht of a V8 Supercar. In this particular case all parties are agreed that the instant centre lines can be taken from the ground (for those unfamiliar with a V8 Supercar, it has a live rear end). Consequently, it forms an excellent basis for comparing the traditional method to the force-based approach. To review the traditional approach to anti-dive and anti-squat, if the moment due to acceleration / braking torque is placed at the hub (in an outboard braking and live axle case) then the equivalent pitch centre is given by,

$$Pc = wheelbase*\tan(Ic) \quad (8)$$

The force transmitted straight through the tyres is,

$$L = Fx*\tan(Ic) \quad (9)$$

Reviewing figure 4 and equation (9) it can be readily be shown using the traditional approach that equation (9) is identical to equation (7). So here we have a conundrum: the forces being applied through the suspension geometry are identical. However, comparing equation (6) to (8), the traditional approach will give a pitch centre nearly double the force-based approach (based on a 50/50 weight distribution). As can be seen, that presents us with a little bit of a problem. So, to compare the two approaches, let's look at some simulated data compared with some actual V8 Supercar data. The first simulation was done using the force-based method, the second method was done using the traditional approach outlined in equations (7) to (8). The comparison of the pitch centres is shown in table 1 below, the results in figure 5.

To outline the traces to the reader, the actual data is in red, the force-based approach is in black and the traditional method is in green. For the purposes of doing a back-to-back comparison, the pitch centres had to be fixed, and this is why the data wasn't going to be an exact match. That said, what is abundantly clear is that the force-based method is doing a much better job of matching the actual data than the traditional method. This is clear in watching the peak damper movements in braking and acceleration.

TABLE 1

Comparison of pitch centres for the force-based and traditional approach

	Force-based approach	Traditional approach
Front pitch centre	50mm	100mm
Rear pitch centre	90mm	180mm

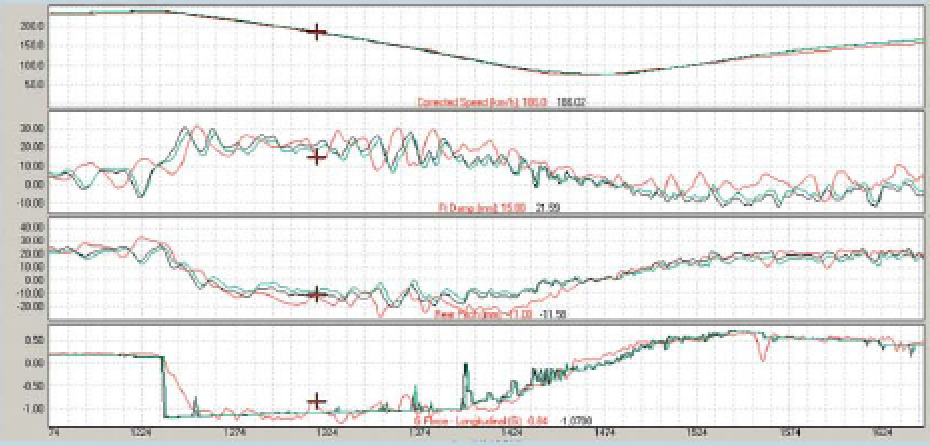


Figure 5 Comparison of actual data to pitch centres modelled by the force-based approach and the traditional method

So the question is, if both the force-based method and the traditional method return the same loads, what in the world is going on with the pitch centres? Well, the devil is in the detail. Taking the anti-dive definition from Milliken[4] we arrive at equation (10). To get to equation (8) I multiplied the top and bottom of equation (10) by the wheelbase.

$$anti-dive-front = \frac{m(a_x/g)(\%front\_braking)*\tan(\phi_{IC})}{m(a_x/g)*(h/wb)} \quad (10)$$

Focusing our analysis on the front, upon reflection what I then did was compare the ratio of the moments. So, the moment by the force reacting at the front due to braking is given by equation (11). If we subtract this from the total moment being supplied by the longitudinal force Fx acting over the c of g, it can be shown that the moment being applied to the sprung mass is as in equation (12).

$$M_{SG} = anti\_dive\_front \cdot \frac{F_x \cdot h}{wb} \cdot a \quad (11)$$

$$M_{CG} = F_x h - anti\_dive\_front \cdot \frac{F_x \cdot h}{wb} \cdot a$$
$$= F_x \cdot \left(h - wdr \cdot wb \cdot \tan(\phi_{IC})\right) \quad (12)$$

The astute reader will quickly recognise this is the same moment arm as the force-based centre. I invite the interested reader to derive equations (11) to (12) on their own. The identity you'll need to do this is:

$$a = wdr*wb$$

What is clear from this analysis is that the traditional method of anti-squat doesn't actually return a pitch centre at all, it's simply measuring the ratio of load change. Yet it is the biggest mistake I see in so many papers and theses presented to me by students and professionals. They take this anti-dive measure and then apply it to work out moments about the c of g. This to me is the biggest downfall of the traditional method. Yes, it returns a load change, but it misses vital information about the forces and moments being applied about the c of g. The beauty of the force-based approach is that it is immune from this misconception.

I stated earlier that I had an addendum to add for deducing the force-based pitch centre. This was the case where the torque reaction to the applied torque is applied at the chassis, as opposed to the upright. This was

CASE STUDY – V8 SUPERCAR

something I overlooked in my first article. In this case, the FBD is shown in figure 6, right. Applying force equilibrium and taking moments about the ground it can be shown that,

$$\sum F_x = 0$$
$$F_x = F_1 - F_2 \cos(\theta)$$
$$\sum M_x = 0$$
$$0 = F_x \cdot R - \frac{R}{2}\left(F_1 - F_2 \cos(\theta)\right) - F_x \cdot R$$
$$\therefore F_2 \cos(\theta) = \frac{1}{2} F_x$$
$$\therefore F_1 = \frac{1}{2} F \qquad (13)$$

Let's now consider the sprung mass. The free body diagram of this is illustrated in figure 7.

Taking moments about the c of g and resolving this it can be shown as in equation (14), right.

Substituting the terms in from (6) and working through the algebra it can be readily shown,

$$\sum M_{c.g} = F_x\left(h - \frac{a \cdot \tan(\theta)}{2}\right) \qquad (15)$$

So, in this case the force-based pitch centre is given by,

$$fpc = \frac{a \cdot \tan(\theta)}{2} \qquad (16)$$

To determine this graphically, we follow the same procedure as per figure 4, but simply drop the instant centre by the tyre rolling radius and take its slope from the ground.

As far as I am concerned, the above formulation is absolutely obvious for inboard brakes and the DeDion axle and on paper should be obvious for an independent double wishbone or a MacPherson strut rear suspension system under acceleration. But what about the last case? Consider this data trace that shows a ChassisSim simulation of a high downforce open wheeler compared with the real data trace. So the reader is aware, the car in question produces over 400bhp at the flywheel. Due to confidence reasons I have to be very tight lipped about where this data came from, which is why I've removed scalings from the traces. What I can tell you though is the top trace is speed, the middle trace is rear damper travel and the bottom trace is throttle. However, I would draw the reader's attention to the fact that the slope of the data traces when the speeds are equivalent is very similar. This is particularly apparent coming out of the turn.

This is a very strong indication that we have correctly modelled where the pitch centre is. I will be the first to admit that what is going on mechanically with the car could be overshadowed by the aero. That being said, my experiences would indicate otherwise. However, on this one I'm happy to be proved wrong. This really forces the question that for a double wishbone and MacPherson strut arrangement, where exactly are these torques being reacted?

In closing then, I trust this article has clarified what I said in my previous article. In particular, the major positive I see from this is that we have delved more into the nature of the force-based pitch centre, and de-bunked a few myths and misunderstandings along the way. The advantage of the force-based pitch centre is that it gives a much more intuitive feel for what is going on and how the forces get reacted through the suspension linkages and the sprung mass. If this is the only thing to come as a result of all this, then I have succeeded in my original intentions.

Figure 6

Free body diagram of the wheel with the torque being applied at the chassis

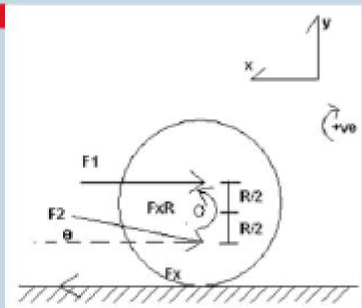
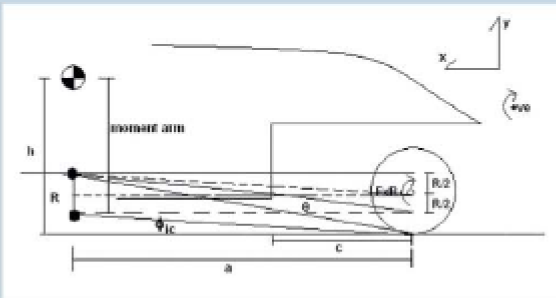


Figure 7

Free body diagram of the sprung mass with torque applied at the chassis

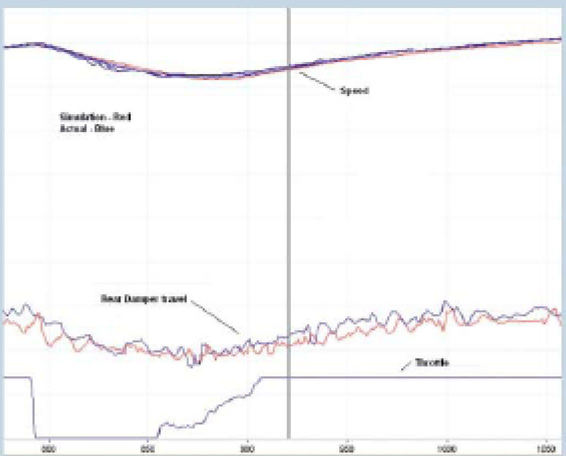


Taking Moments about the centre of gravity and resolving this it can be shown that,

$$\sum M_{c.g} = F_1\left(h - \frac{3R}{2}\right) + F_2 \cos(\theta) \cdot \left(h - \left(\frac{R}{2} + c \cdot \tan(\theta)\right)\right) - F_2 \sin(\theta) \cdot (a - c) + F_x \cdot R \qquad (14)$$

Figure 8

Actual rear damper travel vs simulated damper travel with the pitch centre modelled at the instant centre location



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Bespoke solutions

Pit lane equipment specialist expands product line up to cater for racers' needs

CES (Europe) Ltd will be a new name to Autosport Engineering next January. It's not that the operation will be unfamiliar, Capital Equipment Services has already exhibited three times at the show but, at the beginning of August this year, it became a limited company and changed its name. The move reflects the growth – both of the company and of its worldwide client base – that have taken place since Tony Giles first set up in business in 1992 selling extraction systems for composite, solvent, fume and vehicle exhaust, as well as welding products.

The change of name has been accompanied by a move to new 1500sq ft premises in Banbury, Oxfordshire, a UK agency for Paoli wheel guns and a promise of new product for the near future. Naturally, the company's website has also been re-deployed to reflect this, with more traffic reported since the name change.

CES is now involved in three main areas, with pit equipment now having been added to the company's portfolio. The original extraction and welding products gave Giles access to race teams, which led to him noticing a lack of bespoke items in the pit lane. As a result, Capital Equipment Services, as it was then, started manufacturing pit lane cylinder trolleys and ancillary items. Since then, pit lane equipment has become its main area of business. CES is particularly proud of the interchangeable and hand-tight nature of its products. As the name suggests, the company's hand-tight stems have been designed for tightening by hand only to any size or type of cylinder up to 300bar, without the need for spanners and the danger of over tightening.

More trolley designs are now on their way, while high flow wheel gun regulators, which are currently being tested by two Formula 1 teams, have recently joined the CES product line up. To these is shortly to be added the Pitrunner, which is being introduced to meet next year's changes in a number of racing series. This will take out of the equation all the lines and booms that are currently used for air jacks and wheel guns in racing. Details of the Pitrunner's self-contained air jack and wheel gun system have yet to be released but, as this was being written, product was being prepared to send out for initial testing.

CES's innovative product line up includes this neat double bottle pit trolley

PENNY + GILES LAUNCH THE INNOVATIVE SRH280DP SENSOR

Penny + Giles has launched the SRH280DP, a new hall effect rotary position sensor for motorsport applications. The 28mm diameter angle sensor is aimed specifically at arduous high-duty cycle position feedback applications in all areas of motorsports, such as sequential gearboxes, throttles and suspension measurement. For motorsport applications, the sensor has a 5Vdc supply and 0.5-4.5V ratiometric output with redundancy that will suit the majority of motorsport applications. The SRH280DP non-contacting position sensor is easily installed in space restricted areas using two radial mounting slots on a 38mm PCD.

NEW SUSPENSION FROM KONI UK

Koni UK will be unveiling a new range of Volkswagen-Audi Group dampers and suspension components. The expanded FSD damper range now covers the current-model Audi TT, Audi A4 range from 1994-2001, and the Mk5 VW Golf GTI.

IMPROVED STEERING RIG FROM DC ELECTRONICS

DC Electronics will display a new and improved version of its electronic, power-assisted steering rig at Autosport International. The British wiring specialist will also showcase its new mix and match hardware packages, which have been developed by working closely with different hardware manufacturers, allowing the company to design and manufacture seamless electronic systems, consisting of hardware from a variety of different technical suppliers.

David Cunliffe, managing director, and a regular visitor at the show commented: 'These new packages give the customer the best possible systems available to suit their specific application and budget, and we find that Autosport International is a really great place to showcase new products.'

Making the right choice

TONY TOBIAS

With the increasing number of motorsport industry shows, Tony Tobias advises on how to decide which are the most effective for you

Consider the following: in the present climate there is slow economic growth; many companies are electing to cut their marketing budgets as a result; trade exhibition companies are trying to establish new events that will compete for part of that reduced marketing spend; this expansion means both potential exhibiting companies and visitors will find it impossible to attend every event, leading to confusion and concern; the likelihood is that a certain number of key exhibitors and visitors will be missing from every event, so that none is comprehensive and representative of the industry as a whole.

Given all that, selecting the right event from a plethora of exhibitions can make or break your business. It is therefore essential you select from the correct sector of exhibitions, analyse the options open to you and then decide on the most relevant for your needs.

PEDIGREE

The credentials of any show can be established by checking how long it has been going and its relevance to the products or services you offer. Also consider the exhibition's ability to attract the market leaders to exhibit and the decision makers to visit, as well as the level of advertising and promotion for the event.

Talk to other people in your sector and ask if they have attended the event at which you may be interested in exhibiting.

Select the country that has the buyers to whom you need to promote your products.

When you receive an invitation to attend an exhibition, before you agree, it's important that you understand whether it's a sales presentation or a trade show – some of the concepts may be similar, but their purposes are entirely different.

> "Undertaking research... before deciding to book is essential"

RESEARCH

Undertaking research about the exhibition before deciding to book is essential. Many companies fail to do this, have poor results, and are then out of pocket and put off exhibiting at future shows. Simple ways of researching a show include requesting last year's exhibitors' list and attendance records from the organisers and speaking to exhibitors regarding their experiences and return on investment (ROI).

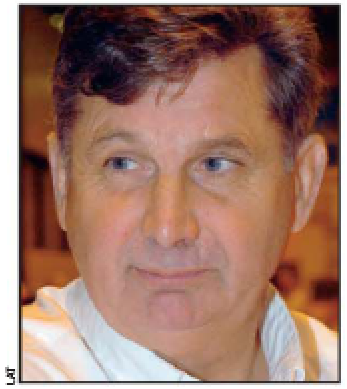
As the market gets tougher, increasing numbers of people are turning to alternative ways of generating new business – cold calling, marketing and, in particular, attending exhibitions.

For most businesses, their experience of exhibitions, conferences and road shows is fairly limited. They have perhaps attended a few, maybe even exhibited at one or two in the past, yet are still unsure as to how to get the best return on investment from them.

The fact is, exhibitions should be an important part of any company's business promotion activities, so my best piece of advice would be to make certain to choose the tried and tested product as this is the most likely to reward you in terms of sales.

If your company has the resources to exhibit at an unproven event, that's fine, but do so in the knowledge that there is a risk it may not deliver everything you require in terms of attaining your marketing and commercial goals. R

MICK HYDE
THE INTERVIEW


LAT

Q Anything new at Radical?
There's always something new, as the cars have evolved considerably over the years. For instance, the SR3, which is our most popular car, has a new Suzuki engine this year, tuned by Powertec and with titanium valves. We are actually the only company that has a contract with the factory for the supply of new Hayabusa engines.

The SR3 also now has all new aero bodywork and chassis. The SR8 underwent a major aerodynamic development last year, and the SR3 has benefited from much of that work. Much of it is based on the experience we have gained with the Le Mans car [the SR9].

As with the SR8, this year we've also passed the full FIA crash test with the SR3 (both with spaceframe chassis) and we're the only people to do that. They have passed a test that is almost identical to that which our carbon chassis Le Mans car has to pass.

Q You must be pleased with that, as Radical has always been a champion of spaceframe racecars?
Yes, we've always been of the understanding that they are as safe, yet obviously a lot cheaper to manufacture, than carbon. In fact, when we were about to produce our Le Mans car, the plan was to do it as a spaceframe chassis. I was talked out of that, though I wish I hadn't been because we've since proved that the only downside is maybe five kilos in weight, but you then have something that's a fraction of the cost

In fact, we sort of have one Le Mans spaceframe car with the SR8 LM. Okay, it doesn't comply with the Le Mans Series regulations, but it goes nearly as quick!

Q What about your Le Mans car, the SR9, what is its future?
We don't plan to build any more at the moment. Our future is really with our other five models and expanding globally. We've spent the majority of our effort expanding our distributor base.

Q So Radical has gone global?
80 per cent of the cars we make we export. Our best markets are China, Mexico, the Emirates, Australia… that's both racing and track day cars. I'd say across the world the majority of the cars end up being raced, but I'm not sure of the exact split between the two.

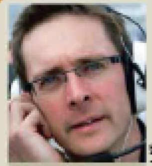
Mick Hyde, co-founder and managing director, Radical Sports Cars
1996: set up Radical Sports Cars in partnership with Phil Abbott after a career in marketing. Company specialises in LMP-styled, motorcycle-engined racecars and track day specials (though its SR5 uses the Honda V-Tec car engine) and also produces the SR9 LMP car. The current range includes the SR8 LM, which uses the V8 engine built by Radical's engine division, Powertec.

Q How many cars has Radical produced in the 13 years since the company was founded?
It's about 900 now, I think. But it may be closer to 1000. We build about 150 a year, but of course we weren't building that many right from the start.

Q What are the plans for the future?
We're heading off for an attempt to lower our lap record around the Nürburgring soon. Michael Vergers will be making the attempt in an SR8 LM, powered by the 2.8-litre, 460bhp Powertec engine we make ourselves.

More long term, we're looking to do an around-the-world race in an electric Radical. We're in partnership with Imperial College London, and it's going to be an electrically powered SR3. The race is in the spring of next year and there are about six or eight cars from different continents taking part. We are the only representative from the UK.

RACE MOVES


Andrew Shovlin


Nikolas Tombazis

Brawn GP race engineers, **Andrew Shovlin** and **Peter Bonnington**, joined driver **Jenson Button** in the London Triathlon recently. Meanwhile, Button revealed that part of his preparation for the running, swimming and cycling event involved a spell of aero work – sitting on his bike in the team's wind tunnel!


Peter Bonnington

Mike Mossholder is the new vice president of sales and marketing at the Las Vegas Motor Speedway. It's his first position in motorsport after working in horse racing and American Football in the past.

Glen Seton, a two-time Australian Touring Car champion, has left his post as race engineer for the Bottle-O racing Australian V8 Supercars team. The team driver, **Tony D'Alberto**, is now looking for a replacement engineer.

Ferrari's head of aerodynamics, **John Iley**, is to leave the team at the end of this season. He joined the Scuderia in 2003 after spells with Jordan and Renault. **Nikolas Tombazis**, chief designer at Ferrari, will take on more of the aerodynamics work at the team from 2010 onwards.

Martyn Dobson, a former British Formula 3 Championship race engineer and the boss of UK club racing operation 4D Motorsport, has died of cancer.

GP2 squad iSport has taken on reigning A1GP and former GP2 ace **Adam Carrol** as a driver coach. Meanwhile, **Oriol Servia** has taken on a similar role with Indy Car squad Andretti Green Racing.

A team from **McLaren F1** won the 2009 ATL F1 Karting Challenge, with Pescarolo Sport and Braun GP completing the podium. There were 26 entries in all, with multi-driver teams from most F1 outfits and many other motorsport organisations, including a team from *Racecar Engineering*, which finished in a dismal 20th place.

RACE MOVES


LAT

Malcolm Wilson

Ford WRC boss **Malcolm Wilson** has been awarded a College Fellowship from Myerscough College in Preston for his achievements in the motorsport industry. The award comes hot on the heels of his OBE.

Shane Howard is the new chief operating officer for V8 Supercars Australia, having been promoted from the position of V8 Supercars event general manager. Meanwhile, current in-house general counsel, **Adam Firth**, has been promoted to general manager – legal and commercial. The organisation is still looking for a new CEO in the wake of the departure of **Cameron Levick** in June.

Joie Chitwood III is the new vice president


LAT

Joie Chitwood III

of business operations at the International Speedway Corporation. Before he joined ISC Chitwood filled the post of president and chief operating officer at the Indianapolis Motor Speedway.

International Speedway Corporation vice chairperson and CEO **Lesa France Kennedy** is to be the keynote speaker at the inaugural Motor Sports Business Forum, North America. The Forum takes place on 8-9 December, in the run up to the Performance Racing Industry trade show in Orlando, Florida on 10 December.


LAT

Richard Petty

NASCAR legend **Richard Petty** has moved to quash rumours that he's to cut the number of cars he runs in the Sprint Cup under the Richard Petty Motorsports banner. However, he said there will probably be some personnel swaps between the cars, after the organisation laid off nine employees in the summer.

Moving to a great new job in motorsport and want the world to know about it? Or has your motorsport company recently taken on an exciting new prospect? Then send an email with all the relevant information to Mike Breslin at bresmedia@hotmail.com

YOUNG ENGINEERS

In the groove

SCALEXTRIC4SCHOOLS CHALLENGE UK FINALS, SHEFFIELD, 10 JULY 2009

Teams from 10 schools, with children aged between 11 and 17, pitted the slot cars they had designed, manufactured and developed themselves against each other around a facsimile of Silverstone for the top spot on the podium at the recent Scalextric4Schools final. Scores from race times and fastest laps combined with assessments by the judges of the design presentations and portfolios decided the UK champions.

'The most impressive thing we've seen is that some of these 11 and 12-year olds are performing some quite complex design tasks,' said Roger French, md of Root Solutions, the PTC re-seller responsible for Hornby, the parent company of Scalextric. 'It's a whole process, not just a design exercise,' he continued. 'It encompasses all the aspects you would find in concept, design and manufacture anywhere in industry.'

In the end, Wootton Upper School, Bedfordshire, was the overall winner, the team having completely re-designed their car, including making their own chassis, developing and improving the gearing and working on minute c of g and ride height adjustments.

'We didn't have a milling machine, so we outsourced the final body moulding,' explained Mark Herd of the Wootton team. 'We sent the final design for the body to be made into a polyurethane mould for vacuum forming in a very thin polycarbonate material for maximum weight saving.'

Runners-up were St Augustine's High School, Scarborough and Queen Elizabeth Grammar School, Lincolnshire, while the

The winners: Wootton Upper School, Beds

Best Engineered Car award went to an all-girl team, aged 14, from Sandbach School in Cheshire.

Scalextric4Schools is a partnership between Hornby and PTC, with help and sponsorship coming from Boxford Ltd, the leading manufacturer and supplier of CAD/CAM systems and CNC equipment to education, and CR Clarke, a company which specialises in the design and manufacture of equipment for the thermoforming, fabrication and recycling of thermoplastic materials.

Hornby and PTC announced at the finals that they would be running the event again in 2010 with a sister series in North America. Discussions are also taking place with teacher networks in Australia and the Far East, with a view to launching the challenge in those regions soon. 'Scalextric4Schools has been a great success this year and we hope it will grow and expand into other regions of the world so that children from other cultures will be able to experience the same sort of buzz that the finalists experienced here,' concluded Tim Brotherhood, education market manager for PTC.

Information, downloads and links to purchase parts and track are available on www.scalextric4schools.org

Handmade chassis, one-off polycarbonate bodies and race-developed gearing were just some of the tricks employed by these bright young engineers

FORUM

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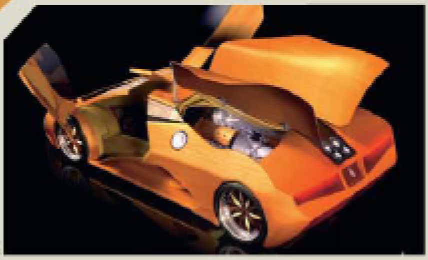


Wood you believe it? Splinter, the one-off wooden supercar

WOODEN PERFORMANCE

I was most interested to read the recent article by Forbes Aird (*Racecar Engineering* V19N9) concerning wood as a structural material. I have long had great regard for the wooden Mosquito aircraft and am also aware of Marcos' exploits with wooden cars. As such, the concept of a wooden chassis racecar is one I ponder occasionally.

One thing that bothers me about the use of wood, however, is crashworthiness. I have heard a number of tales of Marcos cars reducing themselves to matchwood in severe impacts. Couple this to the known dangers of flying splinters, as established back in the days of wooden warships, and a definite safety issue begins to emerge. This aspect of the use of wood was not tackled in Mr Aird's otherwise excellent article. I have considered one or two basic solutions to the problem but would be most interested if the matter could be addressed in the pages of *Racecar Engineering* at some future time.

David Tucker
via email

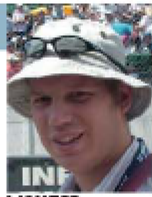
FORBES AIRD RESPONDS:

Thanks for your query regarding the crashworthiness of wooden vehicle structures. You raise an interesting point. I think there are three aspects to this:

1) *The total amount of energy absorbed per foot (say) of structure damage. In principle, this is a matter of the area under the stress / strain curve. On that basis, wood should soak up just about as much energy per pound of structure as any other material (ie most metals), having roughly the same ratio of E/D and similar per cent strain to fracture.*

2) *The rate at which the energy gets absorbed. This will determine*

STRAIGHT TALK



WOUTER MELISSEN

Carry on privateers

Should single engine / chassis combinations be banned in LMP2?

The strength of Sportscar racing is often measured by the manufacturer involvement and participation. The continuity of the sport, however, is ensured by the private entrants and drivers, who tend to stick around a lot longer than the big marques with their multi-million programmes that often only last three years. So it is in everybody's best interests that the privateers can find a spot on the grid and, more importantly, a class where they can fight for the victory.

To cater to the privateers' needs the Automobile Club de l'Ouest (ACO) created the LMP2 class. Unfortunately, that class has been hijacked by manufacturers like Porsche and Acura, who discovered P2 to be a relatively cheap route to class and even outright glory. These semi-works P2s, piloted by some of the most talented drivers, make it utterly impossible for smaller teams to challenge.

The ACO has tried to address the situation by rejecting all-pro line ups in the European events, but the complete domination of the Porsche RS Spyder in the Le Mans Series and at Le Mans showed that to have had very little effect. It can only be a matter of time before gentleman racers like Miguel Amaral, Mike Newton and Jacques Nicolet realise that they either need to spend well over $1 million for a winning car or settle for runner-up positions in cars that cost but a fraction of the Porsche.

A drastic but simple change to the regulations of the P2 class could get the desired result. Ban one-manufacturer cars. If P2 cars have to feature a chassis from one manufacturer and an engine from another, it will not be as interesting for mainstream manufacturers.

> "Ban one-manufacturer cars"

Furthermore, suppliers should be forced to offer their chassis or engines to all teams on the grid, perhaps even at a capped price. Companies like Lola, Oreca and Pescarolo are capable of supplying the chassis, while Judd, AER and Zytek all have a choice of engines available. Manufacturers like Ferrari, Acura or Porsche could still serve as engine suppliers, should they insist on a P2 presence.

It is imperative that the sport's governing bodies realise that, although having manufacturer presence is good for attracting media attention, it is the loyal privateers that have enabled Sportscar racing to thrive uninterrupted for so long. These privateers need to be cherished and the best way to do this is to provide them with an affordable and exciting entry-level class. With a little thought, a revised LMP2 class could be just that.

Cars like the Porsche RS Spyder have taken the fun out of LMP2, forcing privateers into LMP1

FORUM

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LAT

The wooden-chassis Marcos, safe at any speed?

the accelerations sustained by the driver. This factor has much more to do with the geometry of the structure than with the material it's made from.

3) 'Flying splinters'. Wooden warships were made from large, monolithic chunks of wood, not plywood. Yes, when you break plywood (surely you have done this at some point) the bits wind up with jagged edges (ditto for carbon fibre or glass), but you don't exactly get flying splinters, do you? The cross-plying of the fibres pretty much assures this. Restraining any jagged bits from potentially impaling the driver might be achieved with a layer of Kevlar over the interior surfaces.

As to Marcos cars 'reducing themselves to matchwood', Ortenburger cites three cases of Costin's wooden chassis involved in crashes – two in racing (a Costin Sports Racer that did four complete end-overs at over 100mph and a Protos that 'was cut off in a high-speed corner and slammed into a trackside barrier'), plus a road accident involving an Amigo, with Costin himself driving, which struck 'solid Welsh walls' at about 55mph. All three drivers were essentially unscathed.

While I feel sure that no wooden chassis could meet the FIA's crashworthiness criteria for an F1 car – at least not without an horrendous weight penalty – I wouldn't mind betting that a wooden road vehicle structure could be constructed that would meet contemporary safety regulations for passenger vehicles and, as the above examples suggest, a satisfactory level of protection for many race applications.

I hope this goes some way toward answering your query.

GRAVEL TRAP

Shut up and drive

SAM COLLINS

Know your car, but know your driver as well

Drivers are just people, they have different ways of doing things and different personalities. It sounds bloody obvious when you say it like that but there are so many engineers out there who fail to understand that the driver, like the rest of a racecar, is an important and tuneable component. They all too often fail to realise that treating them correctly is often the difference between victory and mediocrity.

There are those that need to be constantly encouraged, others that need to be criticised and then those who just need to be wound up before they work, but all need very different approaches. I speak from experience as a driver and know what makes me drive well. It's simple – make me angry and make sure I respect your engineering ability. If something on track or over the radio winds me up I go faster. If I'm content I go slowly. If I think you are just a jumped-up mechanic I'll find problems with the car, and go slowly whilst thinking about them, rather than getting on it.

> "the driver is an important and tuneable component"

Think back to listening to Felipe Massa's radio transmissions earlier this season when he got agitated about something on track, and engineer Rob Smedley's response: 'Felipe baby, stay cool.' It worked. Massa shut up and drove.

I know a driver contracted to drive in a high-profile series. He was about to join a new team, and the money men had chosen the technical staff. First, they tried to find a different driver, then they told the money men that 'all drivers are like children – none of them have a clue and they have tantrums.' Perhaps not the best thing to say in earshot of the driver, who already doubted the team's ability. It was clear there was never going to be harmony between driver and engineer and, as such, never a competitive team. In my job I get to meet engineers from all levels of the sport. Those who know what they're doing are always open minded and never afraid of saying 'I don't know', while those who are more limited in their abilities get defensive when challenged and spend a lot of time trying to prove others wrong.

Another engineer, an ex-driver, gave a very good presentation at SAE MEC last year in Concord, NC, saying all too often the last thing engineers and team bosses tell drivers before a session is 'don't crash', leaving the driver thinking about nothing but crashing. At Mallory Park, England, an engineer was heard telling a Formula Vee driver that the car was 'running super fast and handing well, so you'll really smash it up good and proper this time', following it up with 'remember, you pay for repairs.' The result was the driver, who normally qualified 20th or worse, put it third with a wild lap, though admittedly crashed in the race itself.

At the Monaco Grand Prix a few years back, Fernando Alonso was coming up to lap Renault team mate Giancarlo Fisichella when the latter's engineer got on the radio: 'Come on mate, Fernando's gonna lap you, you can't be this slow.' As if by magic, the Italian came alive and started overtaking and improving his speed. I suspect Fisichella was suffering from what I call brain fade – when you are driving and you get into a rhythm and your mind drifts. Your lap times get worse and you have no idea why, then something wakes you up and you pick up the pace.

There is no right or wrong way to deal with drivers, but you do have to set up a driver for a race like you set up a car. You need to get to know the driver, know what his likes and dislikes are and know what motivates him. It doesn't matter what it is, what really counts is the chemistry and understanding between team and driver.

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LATE APEX

Common sense prevails

The election campaigns of Messrs Todt and Vatanen for the FIA Presidency are well under way, and regardless of which man wins, it is to be fervently hoped that one of his first moves once in office will be to sort out, once and for all, the stewarding system, particularly with regard to Formula 1. A prime argument for this is the penalty slapped on the Renault team for a botched pit stop at the Hungarian Grand Prix.

The background is that Fernando Alonso had claimed pole position for Renault on what turned out to be a very light fuel load. Predictably, he powered into the race lead, but then dove into the pits on lap 11 for fuel and tyres. On re-entering the circuit, he reported that he was coming back to the pits with what felt like a deflating tyre. Shortly thereafter, the right front wheel retaining device came off the car at turn 5, with the wheel and tyre doing likewise at turn 9. Alonso managed to drive back to the pits, but that was effectively the end of his Hungarian Grand Prix.

After reviewing the incident, the FIA stewards imposed what can only be described as a draconian penalty. They suspended the Renault F1 team from the next race – the European Grand Prix in Valencia – for breaching Article 23.1.i of the Sporting Regulations, which involves releasing a car after a pit stop when unsafe to do so. On this point, there can be no argument that the team was guilty as charged.

It is pertinent to mention here that all of this took place against the backdrop of the Saturday incident at the Hungaroring, in which Ferrari driver, Felipe Massa, was hit by a third spring from Rubens Barrichello's Brawn, and a week earlier, a Formula 2 accident at Brands Hatch, in which Henry Surtees died after being hit by a wheel from another competitor's car.

Summarised, the stewards' justification for the penalty was that Renault had knowingly released the No 7 car from the pit stop position without one of the wheel retaining devices securely in position. Furthermore, the stewards claimed that being aware of this, Renault had failed to take action to prevent its car from leaving the pit lane and failed to inform the driver of the problem or to advise him to take appropriate action.

The French national motorsport authority, the FFSA, on behalf of Renault F1, lodged an appeal against the severity of the penalty. This was heard by the International Court of Appeal, on 17 August 2009. After listening to the submissions of the FIA and Renault F1 legal teams, the ICA – quite correctly, in my view – allowed the appeal and overturned the stewards' sanction, issuing a reprimand and imposing a fine of $50,000 in its place.

> "it had no motive for... allowing its car to leave the pit lane with, in effect, three wheels"

In fact, the ill-considered justification by the stewards' for the original penalty was summed up in a wonderfully dry observation in the Renault F1 team's submission to the court: 'The Appellant [Renault F1] contends that the fact that it had no motive for or interest in allowing its car to leave the pit lane with, in effect, three wheels, constitutes additional evidence of the fact that the infringement was committed unknowingly.'

Ultimately, it was a victory for common sense, but this appeal should never have had to go before the ICA in the first place.

EDITOR
Graham Jones