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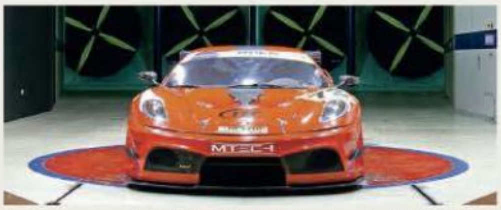
F1 TECHNICAL UPDATE
We analyse the latest aerodynamic changes in grand prix racing

FORD LPG TOURING CAR ENGINE
Why Mountune switched to an alternative fuel in the BTCC

FORMULA LE MANS
Developing Oreca's chassis into the 'LMPC'

AUDI R15+ TDI
LE MANS CONTENDER RESHAPED BY THE RULES

Gas turbine Sportscar
Looking back at a radical motorsport propulsion system



Ferrari F430 GT at MIRA
We study the Italian marque's baby GT racer in the wind tunnel

Fluid dynamics software for free?

How top teams are switching to an open source CFD package

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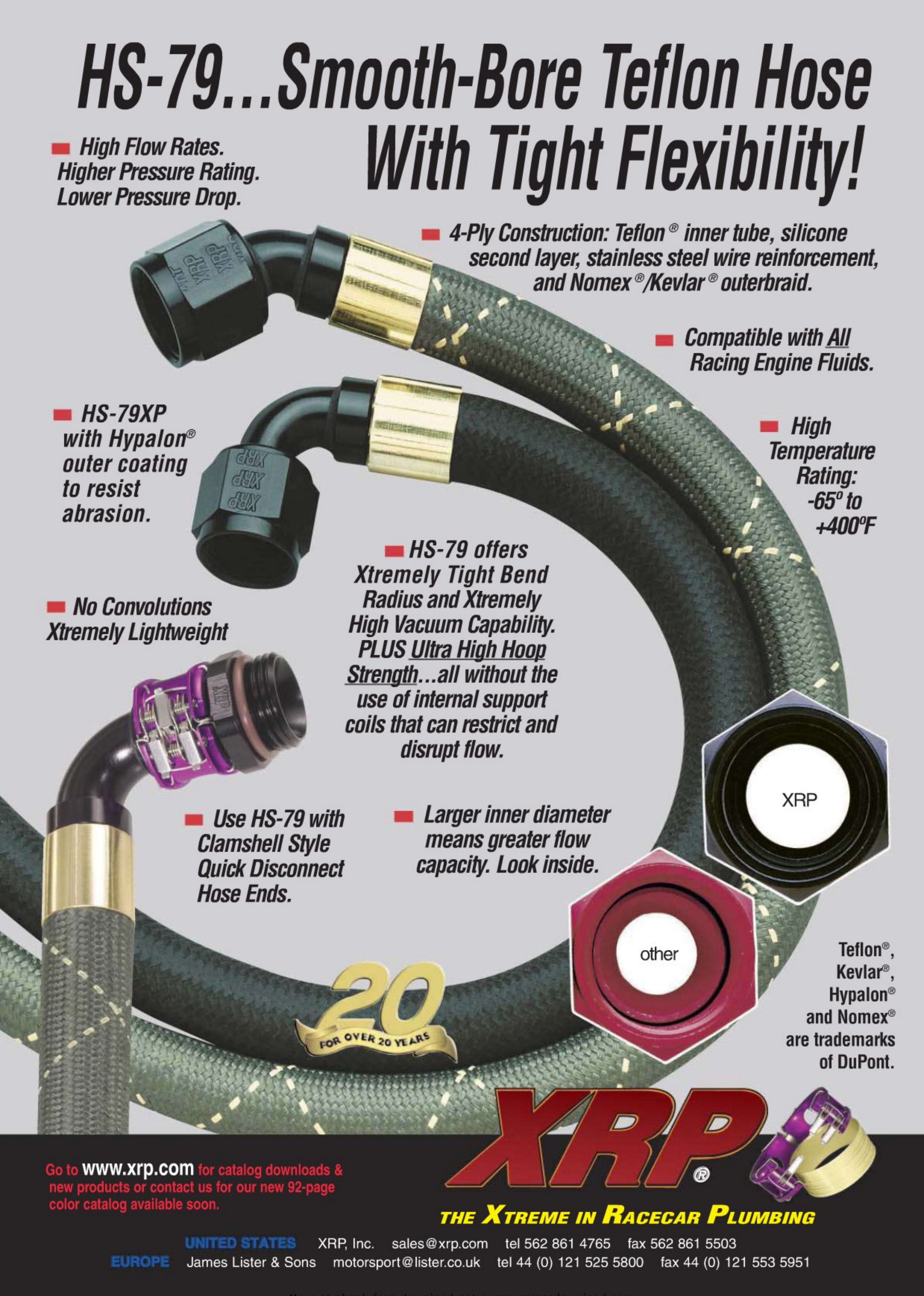
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Well, something has changed around here. That's right, Great Britain has a new government. Well, I assume it has, for as we close for press the pre-election hyperbole is in full swing but, by the time you read this, it'll all be over bar the shouting, of which it's looking like there may be quite a lot. Chris Aylett has an interesting take on the situation, so have a read of his piece on p79 this month. But back to more important matters, Formula 1 is back and already the teams are griping at each other over who has what bit of technology, stalling rear wings, ride height adjusters or flux capacitors. It is all part of the fun of motorsport engineering.

One thing we can be sure of in these uncertain times is that if you come up with something clever, you can be sure that someone else will try to find a way to get it outlawed. This was the problem Audi faced with its R15 Le Mans Prototype. It won't win any prizes in a beauty contest but it is still a fascinating machine. Not least because one of the tools used to develop the car was a free-to-download CFD package called OpenFOAM, and we take a good look at the implications of that this month. You have to wonder with open-source CFD and CAD now readily available, how long it will be before we see the first ever open source competition car project.

Elsewhere, Arena Motorsport is facing up to simllar protests this year over the engine fitted to its Calor-branded BTCC Ford Focus. The opposition think it is unfair because it the LPG-fuelled racecar is very fast in a straight line, but is that really just down to the engine?

One place where there is not much bickering is at the back of the Formula 1 grid. Well, at least not much Bickering over legality, but there is a fascinating battle going on for 10th place in the championship, which brings with it a big cash prize. Oh, and they do a lot of overtaking, so it's great to watch, too. Perhaps Max was right with his £40m cost cap after all?

DEPUTY EDITOR
Sam Collins

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INDUSTRY UPDATE

FORMULA 1

Michelin considering Formula 1 return in 2011

But only if the FIA agree to a series of strict conditions

AS *RACECAR ENGINEERING* went to press French tyre giant Michelin was in discussions with the Formula 1 governing body, the FIA, about a return to the sport in 2011. However, its involvement is said to be dependent on the sport meeting three crucial conditions.

The French tyre manufacturer, which pulled out of F1 at the end of 2006, has admitted it is interested in taking over from current tyre supplier Bridgestone, which is due to end its involvement in F1 at the end of this year, but only if certain conditions are met.

Michelin managing partner, Jean-Dominique Senard, told *Bloomberg*: 'We might consider returning, but there are some very clear conditions, [including] to show the performance they [tyres] can bring, notably in terms of fuel saving and CO^2 reductions.'

Lawrence Butcher

F1 tyres face major changes, if Michelin man gets his way

Meanwhile, Serge Grisin, the company's boss of four-wheeled motorsport, told racecar-engineering.com: 'Certain things have to be done. We must have competition, we do not want to be the only supplier. Also we need to be able to use the opportunity of competition to improve our tyre technology. For example, our new Pilot 3 road tyres had technology developed for Le Mans in them. We need this from Formula 1. Finally, it must have the possibility to improve the green-ness [environmental credentials].'

There has been speculation that Michelin would favour a switch to 18in wheels (from the 13in currently used in F1) should it come back to the sport, which would be in line with its current LMP tyres, as well as moving F1 closer to road car tyre sizes with low profiles, which could prove a plus point for marketing. Grisin has said it would not use the current LMP tyre but perhaps one developed specifically for F1 of the same size.

With Michelin keen to supply teams on a non-control basis there is now the possibility of a tyre war in Formula 1, and Korean manufacturers Hankook and Kumho have also been linked to Formula 1 supply deals in 2011, while Bridgestone is still believed to be in talks with F1 ring master, Bernie Ecclestone, about staying in the sport.

Meanwhile, Ecclestone is also said to have told teams to allocate a tyre budget of around $4m for 2011, as it is unlikely any company will be willing to supply rubber free of charge in the current climate (Bridgestone's current spend is said to be $70m a year).

Michelin's last spell in F1 was from 2001 until 2006. It was not interested in becoming the control tyre supplier when the tender process opened for the 2008 season, even then insisting it was vital the company faced competition if it was to invest in Formula 1.

> **RACECAR SAYS...**
> **Let's hope Michelin gets its wish and becomes one of two, or more, tyre suppliers next year – as nothing livens up F1 more than a tyre war...**

FORMULA 3

Formula 3 Euro Series hit by GP3

THE ARRIVAL OF the all-new GP3 championship seems to have hit the Formula 3 Series particularly badly, with just 13 cars from five teams turning out for the season opener at Paul Ricard.

Teams leaving the championship have been the main problem, with Carlin, Manor, SG Formula, HBR and Kolles & Heinz Union all no longer taking part. Of these, just Manor and Carlin are now in GP3, yet the new spec series boasts a full grid of 30 entries, all budgets that could reasonably have been expected to go to Euro F3 if the new series had not been set up.

Last year the Euro Series had 29 entries and, in a bid to attract more cars to the championship this year, the organisers have now amended the entrance criteria to allow the previous generation of F3 cars to race in a non-championship class. This is likely to result in at least five cars from the German F3 Cup joining the grid for future rounds.

It's not all bad news on the Formula 3 front, however, and the British Formula 3 Championship, historically one of the strongest in the world, boasted a grid of 21 cars at this year's Oulton Park opener, one up on the season-starting race last year. The first meeting of 2010 also featured for the first time its all new three-race format – this year British F3 is running a 30-race programme spread over 10 meetings.

'With 30 races and a bold new format, the Cooper Tires British F3 is on the threshold of a superbly exciting season,' said Stephane Ratel, the chairman of the championship promoter, SRO Motorsports Group. 'The teams are to be congratulated on their efforts in assembling such an impressive entry. It bodes well for the continuing growth and stability of British F3.'

V8 SUPERCARS

Australian V8 plans Car of the Future

V8 SUPERCARS, THE premier Australian motor racing category, has revealed the first details of its Car of the Future (CoF) initiative, aimed at reducing costs and attracting other manufacturers beyond Holden and Ford into the championship.

The CoF, which is expected to hit the track in 2012, will consist of a control floorpan and rollcage, with minor variations to accommodate various different bodywork styles. It will be easier to produce than the current car, the series says, and will be offered to teams in flat pack kit form.

As for the engine, V8 Supercars Australia (V8SA) insists that powerplants must remain V8 in configuration, and it is currently finalising the details of an 'Engine Equalisation Programme' for any suitable variant from any manufacturer that could co-exist with the current Ford and Holden engines.

Front suspension and steering is generally unchanged from Project Blueprint – the current formula the series runs to (see 'Watch this' on p7) – although the CoF also features control independent rear suspension and uprights, plus a change to 18in wheels. The Holinger mid-mounted gearbox remains unchanged, but a move from a spool to a Detroit Locker rear differential is to be investigated for potential introduction. To help keep costs contained, brakes, cooling and fuel system will all be controlled on the proposed new car, as will all the cars' electrics, including the chassis loom, control engine looms and control ECU and data logger.

Meanwhile, V8SA says the bodywork must be substantially representative of the production car model, but with aerodynamic parity with other cars.

Safety has also been addressed and V8SA says it is working with the FIA on improving the driver seat and position. Glass will also be banned and polycarbonate windscreens used instead, while the fuel tank will be shifted from the cars' boot to in front of the rear axle. Target vehicle mass is 1200-1250kg.

CoF head of project, Mark Skaife, said of the new concept: 'Our open shop front policy will be based on potentially attracting additional manufacturers [into the series]. We want to open the door to genuine high volume production, four-door sedans, which will be configured as V8 rear-wheel drive racecars under strict parity arrangements to compete equally against the current [Ford] Falcons and [Holden] Commodores.'

Precise technical details are scarce, but the series has confirmed that it is aiming for a target cost of AUD$250,000 (£152,000 / $233,000) for a rolling chassis, while engine costs are to be halved to AUD$100,000 (£60,500 / $93,000), with a doubling of engine lifespan to 10,000km.

BRIEFLY...BRIEFLY...BR

DURANGO AIMS FOR F1

Former GP2, F3 and F3000 outfit Durango is to apply for the 13th slot in the Formula 1 line up for next season, hoping to take the place left vacant after US F1's failure to make the grid this year. The team dropped out of the GP2 series last year, but has now found backing to race in Formula 1. Other organisations thought to be aiming for the 13th slot in 2012 include Lola and Stefan GP. Applications had to be with the FIA by April 15 and an announcement about which team has made it, along with the team which will be named as first reserve, is expected to be made in July.

STAY AT HOME DOME

Dome has given up its entry in this year's Le Mans 24 Hour race. It is thought the withdrawal is due to a disagreement between the Japanese constructor and its French partner, OAK Racing, over the choice of tyres for the endurance racing classic. OAK, which was to run the Judd-powered Dome S102 coupé, actually races its own Pescarolo LMP2 cars on Dunlops, which it had hoped to use on the S102, while Dome favours Michelins. The Pegasus Judd-powered Norma LMP2 car will now take Dome's place in the Le Mans line up.

HONDA FOR WTCC

There has been speculation that Honda is to make an assault on the World Touring Car Championship through its Argentinean-based Honda Racing TC2000 team. The two-car campaign is to be funded by the Japanese car giant's Argentinean and Brazilian operations. The base car is likely to be the four door City saloon.

Meanwhile, Ford has moved to counter rumours it's also considering competing in the WTCC. Motorsport boss Jost Capito saying there is only room for one programme, and that's the WRC.

• MORE NEWS ONLINE AT WWW. RACECAR-ENGINEERING.COM

TOURING CARS

BTCC u-turn on rear-wheel drive for NGTC

LAT

At around £100k, plus engine, the Next Generation Touring Car will, say series' organisers, be easier to maintain, have greater performance and be half the cost of the current cars

The British Touring Car Championship (BTCC) has released details of its Next Generation Touring Car (NGTC) and the regs now include a reprieve for rear-wheel drive cars.

Cars conforming to NGTC spec, which will use many common components, including the 2.0-litre turbo Swindon-built engine, will be eligible for the BTCC from the start of the 2011 season and there will be performance parity with the current S2000 cars until 2013. From then on the performance of the NGTC cars will be incrementally stepped up.

TOCA, the body responsible for the BTCC, has confirmed that both front and rear-wheel drive formats will be permitted under the NGTC technical regulations, despite RWD being prohibited when the regulations were first announced.

Alan Gow, the BTCC series director, said: 'After we released details of the NGTC programme last year, I stated that we would re-visit the question of incorporating rear-wheel drive in the regulations if there was enough interest or commitment from teams and manufacturers of rear-wheel drive cars to support it. Having now had those discussions, I'm confident there is and so we have now included it.'

GPR Motorsport has been commissioned to carry out the design, validation, prototype manufacture and testing programme for the new subframe / suspension assemblies, for which it will be the nominated supplier, while TOCA has also appointed as technical partners Xtrac, AP Racing and Cosworth Electronics.

A prototype NGTC car will be built and will undergo a comprehensive testing programme, part of which will include it taking part in official practice sessions at the final round of the 2010 BTCC championship.

BRIEFLY...BRIEFLY...BR

CLOUDY SKIES

The Volcanic eruption in Iceland caused headaches for many teams, with Formula 1 teams stuck in China, FIA GT teams stranded in Abu Dhabi and a number of parts suppliers unable to ship components anywhere.

LOTUS LOOKS TO THE EAST

Lotus Racing (the F1 team) is investigating opening a research and development facility in Malaysia. The facility would include a 60 per cent scale wind tunnel, backed by a CFD cluster.

YOU TWEET?

Never one to miss out on the opportunities offered by modern technology, you can now follow *Racecar Engineering* on Twitter. Look up racecarengineer if you are that way inclined.

WATCH THIS

Learn more about the exciting Australian V8 Supercars series by listening to this tech talk by engineers Neil Crompton and Mark Larkham.
Go to: **http://www.racecar-engineering.com/vids**

FORMULA 1

Failure, F-ducts and floors

Having enjoyed a short break after back-to-back races, the F1 circus arrived in China for the Shanghai Grand Prix, with some significant upgrades made to the cars

TORO ROSSO

The Shanghai race weekend started with a bang, when Sebastien Buemi's Toro Rosso suffered front suspension failure. Under braking, the right front upright failed, leading to an overload of the right front upright, which then failed in a similar manner. It transpires the uprights were from a new batch, which had not previously been tested on track, but was there more to it than this? For this year the regulations require the uprights be made from aluminium. However, the Toro Rosso upright is of a similar design to both the 2009 Red Bull Technology cars, which already used an aluminium upright, yet the failure itself occurred around the top wishbone mounting. This caused the area of the upright holding the wheel tethers to fracture, leading to both wheels breaking away from the car. As the car was returned to the pits it could be seen that the remains of the tether attachments were still connected to the car.

Photos: LAT

Toro Rosso suffered a catastrophic front suspension failure in practice

FERRARI

With a major development step expected in Barcelona, Ferrari surprised many by turning up with several modifications to its F10, mainly related to the car's floor. It also now features a more complicated front splitter and changes to the rear diffuser.

Having previously used a simple splitter with an inverted 'top hat' profile to its leading edge, Ferrari has now added an additional vane to act as a flow straightener alongside the splitter, which itself now has a more curved profile. At the rear, the diffuser has a revised central section, with a step in the horizontal element between the upper and lower decks, as well as changes to the positions of the fences running vertically down from either side of the upper deck.

Ferrari unexpectedly turned out with several new modifications to its F10

Red Bull's simplified front end aero, used in conjunction with a new floor

RED BULL

Having run the car largely in the same specification that ran in Barcelona testing, the RB6 had had a number of front-end aero changes. These include a simpler front flap arrangement, with a continuous surface across the span, rather than being broken up into several elements. Likewise, the end plate now has a much larger vent. This is Red Bull's interpretation of the Brawn-style upright-less end plate, as cloned by most teams on the grid.

Another step into other team's solutions is the addition of turning vanes under the nose cone. Most teams run some form of vane in the area beneath the nose and above the exclusion area between the front wheels. Red Bull, although having run a very high nose, have never exploited this area before.

It's often said that vanes mounted so far forwards are more sensitive and less efficient, but the RB6 vanes are very large and the team felt they provided an improvement to the car's aero. These visible changes were made in conjunction with undisclosed under-floor and mechanical changes.

With the clarification to the Parc Fermé rules, Red Bull appears to have lost none of its qualifying advantage. Most of the theories put forward – pumping up dampers, frozen dampers, melting wax bump stops and load-sensitive dampers seem to be countered by the clarification.

FIA CLARIFICATION

'Any system, device or procedure, the purpose and / or effect of which is to change the set up of the suspension whilst the car is under Parc Fermé conditions will be deemed to contravene Article 34.5 of the F1 Sporting Regulations. Such systems could include, but are not limited to, those which rely upon changes

of gas pressure, changes in hydraulic pressure, changes to temperature-sensitive materials or extreme-rate damping.'

One point of note was the extreme amount of rear ballast fitted to the RB6 for the Shanghai race. With the circuit lacking any fast turns, teams needed to focus on traction, though Red Bull appears to have bucked the trend for extreme forward weight bias, by choosing to fit slabs of ballast in the space beneath the gearbox and floor.

WILLIAMS

Despite having its rear wing delayed at customs, Williams had changes to the front wing end plate ready for Friday practice. The new set up sports sharp lips to the upper and trailing edges of the end plate, where the previous version ran simpler, rounded edges in these areas.

F-DUCTS

McLaren has shown that its F-duct system, which allows the driver to stall the rear wing at high speed, is a useful tactical addition to the car. In the opening race weekends the car has shown a clear top speed advantage of up to 10km/h.

With that in mind, it should come as no surprise that several teams have developed similar prototype systems, with three new versions appearing in free practice at Shanghai on the Ferrari, Williams and Mercedes.

Heavy rain meant operation of the McLaren F-duct could be clearly seen

Ferrari ran its own version of a blown rear wing in free practice

However, none of the new systems appear to mimic the McLaren system exactly, and do . not seem to be driver operated.

Of particular note at Shanghai was the fact that the heavy rain meant the McLaren system could actually be seen in operation. As the drivers manouevred their cars into a straight line out of a turn on to the straight they engaged the F-duct and the spiralling vapour trails from the rear wing vanished. Towards the end of the straight, just before the braking area, the trails re-appeared as the driver released the duct, allowing the rear wing flow to re-attach and provide downforce.

Ferrari were the first to run its new F-duct, with a duct leading through the shark fin engine cover into the rear wing flap. As yet, the team do not have the driver-actuated duct fitted to the cockpit, so the system was completely passive.

Taking a different approach, Mercedes had what look like either a passive or incomplete system. With no duct to feed air through to the flap, an oversized fin takes airflow from the rear wing main plane and feeds it on to the rear face of the flap. Two long straight slots are then present at the base of the flap.

+ TECH EXTRA
www.racecar-engineering.com/f1

More updates on the *Racecar Engineering* website

- McLaren's F-duct explained
- Full GP technical previews
- Full GP tech reviews
- Latest comment from key team members

ONLINE RACE-BY-RACE FORMULA 1 TECHNICAL ANALYSIS AT www. racecar-engineering.com/f1

SENSORS

KISTLER T9217A SENSOR

INSTRUMENTATION SPECIALIST KISTLER has introduced a new Type 9217A sensor using an ultra-sensitive PiezoStar element to provide precise measurement of compression and tensile forces. With a measuring range of ±500 Newtons and sensitivity of a few millinewtons, the Type 9217A force sensor is equally suitable for use in both production and laboratory applications. Its rigid construction ensures the sensor is resistant to lateral forces and has a high tolerance to bending moments, helping to minimise interference effects. The sensor weighs 16g, has an outer diameter of 8.5mm, overall length of 28.5mm and an operating temperature range from -80 to +205degC.

For more information see www.kistler.com

RESOURCES

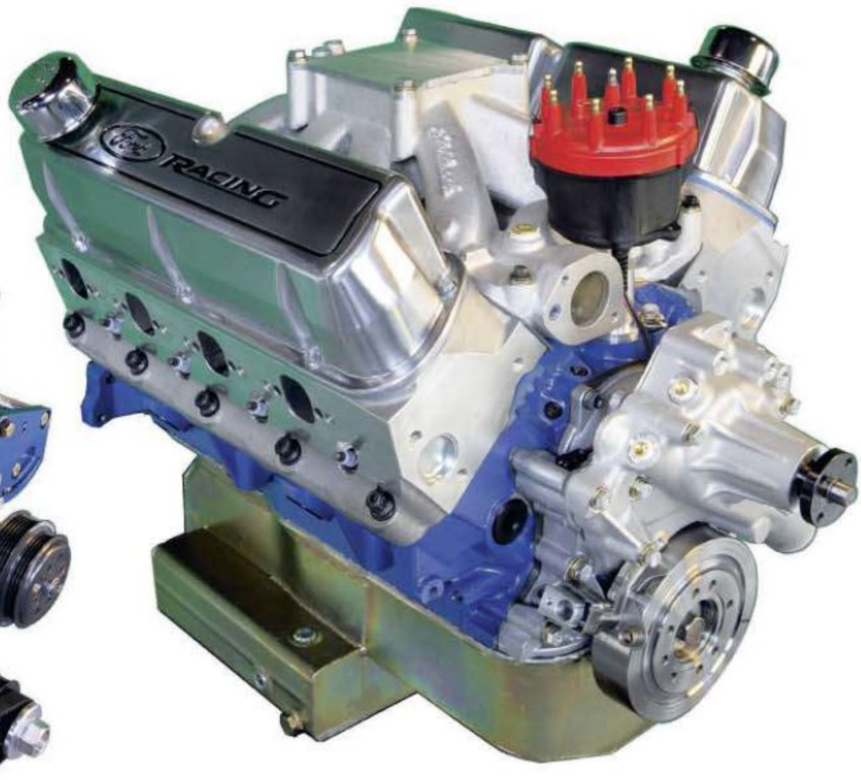
WHO'S WHO IN F1

THE NEW 2010 edition of Who's Who in F1 is now available, covering every aspect of Formula 1, from teams to circuits and technical information. The 2010 edition is printed in hardback with 564 pages and accounts for nearly 50 per cent of personnel who are either new to the sport or have recently changed position. The guide also covers media, sponsors and marketing contacts and, as such, is an indispensable reference source for anyone involved in motorsport.

For more information see www.whoworksin.com

POWERTRAIN

FORD RACING ENGINE

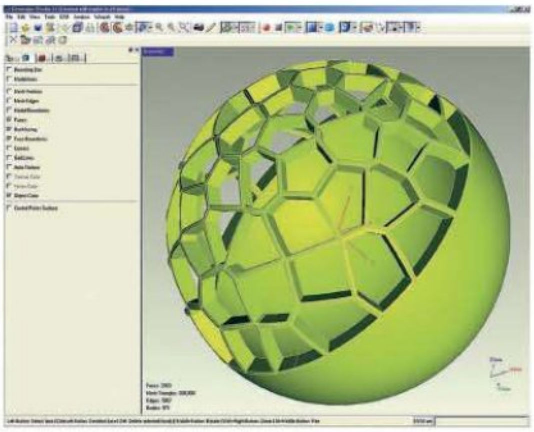


FORD RACING HAS expanded its line of sealed racing engines with the introduction of the new 540bhp S374W engine, specifically developed for asphalt and dirt circle track racing. The engine displaces 374ci (5850cc) and is based on a BOSS 351 block with Eagle crank and rods. Breathing is dealt with by alloy Ford Racing Z CNC-ported heads and an Edelbrock Super Victor intake manifold, while the valvetrain features 1.65:1 roller rockers and a solid flat tappet camshaft. With maximum power quoted at 7000rpm and 470ft.lb torque at 5100rpm the engine has been accepted for competition in both ASA Late Model and NASRA Dirt Late Model series.

For more information see www.fordracingparts.com

SOFTWARE

GEOMAGIC



3D SOFTWARE MANUFACTURER Geomagic has released details of its new Studio 12 software suite, designed to allow seamless transfer of 3D scan data to CAD. The new software will be the only reverse engineering software to directly integrate with CATIA, Autodesk, Pro Engineer, Siemens NX and SolidWorks.

New features include a more intuitive interface, automatic surface and solid trimming and new hole-filling features for polygon meshes. Studio 12 is due for release in early May and will be available in both 32 and 64-bit versions.

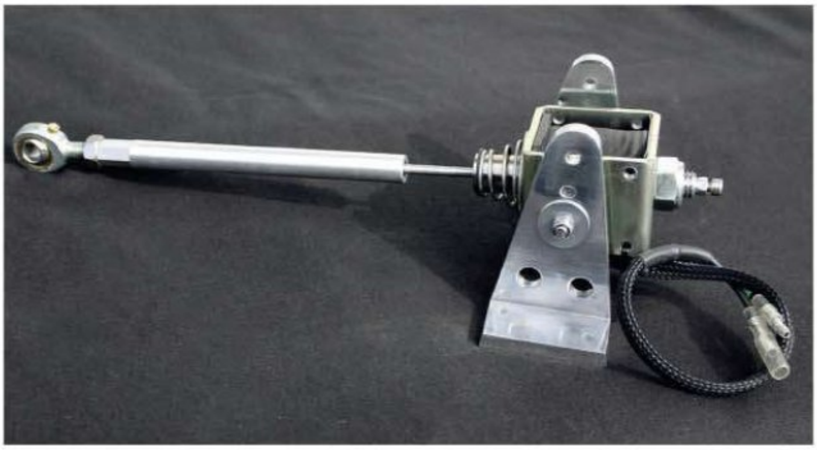
For more information see www.geomagic.com

HARDWARE

PRO SHIFT

FOLLOWING ON FROM the highly successful launch of its Pro-Shift PS3 gearshifting system at the 2010 Autosport Show, Pro-Shift has announced the release of its accelerator pedal auto blip downshifter. As space is often restricted in racecar applications this solenoid-driven device is designed to operate directly upon the vehicle's accelerator pedal, providing clutchless downshifting without the need for the driver to manually blip the throttle. When used in conjunction with the PS3 it can provide variable gear specific 'blips' and will also work in conjunction with the PS3's downshift lock out feature, providing inherent protection from over revving when downshifting, preventing potentially costly engine / gearbox damage.

For more information see www.proshift.co.uk



FLUID CONTROL

LEE PRODUCTS CHECK VALVE

THE NEW 093 check valve from UK based Lee Products is triumph of miniaturisation, being the smallest valve of its type ever developed. The all stainless steel side exit check valve is just 2.5mm and weighs in a just 0.14 grams, yet is still designed for system pressures of up to 4000 psi. Available in forward flow configuration the 093 valve features a hard metal to metal seat to ensure durability and is ideally suited to use in harsh motorsport environments.

For more information see www.leeproducts.co.uk.

On the plus

After a year of battling for supremacy with the Peugeot 908, has Audi regained its Sportscar crown with the newly re-modelled R15+?

BY SAM COLLINS

Audi's R15 took an easy win at the first race of the 2010 Le Mans Series, the turbo diesel car finishing five laps ahead of anyone else. Audi dominance in Sportscar racing is nothing new, but the concept behind the revised version of the R15, the R15+, was. The car was designed with a radical aerodynamic concept focussing on the flow ***through***

LAT

side

"designed with a radical aerodynamic concept"

DR MARTIN MÜHLMEIER, HEAD OF TECHNOLOGY AT AUDI SPORT

the car not *over* the car. 'Instead of guiding a lot of air around the car and creating a lot of expensive downforce (and paying the subsequent drag penalty) you guide it through the car,' explained Wolfgang Appel at the car's launch in 2009.

This meant the front of the R15 was essentially a void, and that opened the door to some significant controversy. Following the R15's victory in the 2009 Sebring 12 Hours Peugeot and Aston Martin questioned the car's front bodywork legality under regulation 3.6.1, which states:

> With the exception of the rear wing defined in article 3.6.3, no bodywork or underbody element having a wing profile (*) is permitted:
>
> (*) "Wing profile": section generated by two arcs with different curves and / or centres joining a leading edge at the front to a trailing edge at the rear, the purpose being to exert an aerodynamic effect, lift or downforce.
>
> Are not considered as wing profiles, the bodywork elements that:
>
> • have a constant thickness
>
> • have an absolutely symmetrical profile
>
> • are vertical

Another manufacturer's lead designer said, 'it's simply illegal, there's no way it should ever have been allowed to run. They need to ban its front aero now because otherwise every other car in the field will have to be re-designed to keep up. It's a front wing and that's just not on.'

The rear of the car was also challenged by rival George Howard-Chappell of Aston Martin, who said, 'The question is what constitutes an aerodynamic opening and what constitutes a radiator duct?'

The dispute rumbled on until Le Mans in June last year when things came to a head. Audi had made some minor revisions to the R15's front bodywork, replacing a mesh screen in the front ducts with a 'horn' of carbon fibre. This was not due to the legality debate, rather that in Sebring trim the mesh had been getting damaged and had collected debris during the race, altering the car's aero balance.

Peugeot ultimately lodged an official protest, stating, 'It would indeed seem that two features of the Audi R15 – in the configuration in which it was shown at technical scrutineering for the 2009 Le Mans 24 Hours on June 8 – do not comply with Article 3.6.2 of the current technical regulations: the flap which links the two front wings, and the appendages fixed to the inner surface of the front wings. These appendages and this flap effectively form part of the bodywork and their sole purpose is to generate downforce. These bodywork parts are considered to be aerodynamic elements. Since they do not appear on the list of aerodynamic elements authorised by Article 3.6.2, they are consequently not permitted.'

Audi's controversial channel concept has seen three clear iterations of the front air duct. At sebring in 2009 *(right)* a mesh panel was fitted ahead of the suspension but debris accumulated there altering the balance of the car. As a result a new solution was found for Le Mans, with a pair of 'horns' in place of the mesh *(below, right)*. The rule changes in late 2009 saw this outlawed, now the R15+ is fitted with a single plane 'wing' in the centre of the duct *(bottom)*

TECH SPEC

AUDI R15+

Class: LMP1

Manufacturer: Audi Sport/Dallara

Chassis: Carbon fibre with aluminium honeycomb

Suspension: Double Wishbone with pushrod actuated torsion bars

Brakes: Brembo carbon ceramic

Transmission: Xtrac five speed sequential

Engine: Twin turbo 5.5 litre V10

Fuel: Shell V-Power LM24 Diesel

Tyres: Michelin

> **"The question is what constitutes an aerodynamic opening..."**
>
> **GEORGE HOWARD-CHAPPELL, ASTON MARTIN**

The 2010 Audi *(above)* has far more conventional bodywork compared to the 2009 version *(below)*. Gone are the dramatic louvres on the side pods and the rear wing sits further back

R15+ retains the 5.5 litre V10 turbo diesel engine

The R15+ has a very similar chassis to the R15, but the nose reshaping was substantial enough to require a new crash test

The protest was rejected by the ACO and so was taken to the FIA, but was eventually dropped.

In the end, the R15 proved to be no match for the 2009-specification Peugeot 908s at Le Mans. Even at Sebring, where the R15 ultimately won, the 908s put in faster lap times. Audi's engineers returned to base and looked for ways to catch up. 'After Le Mans 2009, our specifications for the R15+ listed about 20 key items,' says Dr Martin Mühlmeier, head of technology at Audi Sport. 'Efficiency and reliability were at the top of the list, but we also looked at details like improved night-time lighting of the track. We were able to meet this wish of the drivers with a new headlight concept.

'This year though, the Le Mans regulations prescribe air restrictors with a smaller diameter and reduced supercharging pressure for diesel-powered vehicles,' Mühlmeier continues. 'Due to the reduction of engine power as a result of the regulations we have tried to make the car's aerodynamics even more efficient than before, and to improve the Cd value and downforce parameters.'

> **"Efficiency and reliability were at the top of the list"**

CUTTING DRAG

In 2009, the R15 suffered a deficit in straight-line speed compared to its rivals – it topped out at 330.4km/h, whilst the

Prodrive-developed Aston Martin Lola achieved 336.35km/h and the Peugeot 340.86km/h. So cutting drag was a clear priority for Mühlmeier. 'With an open car it is a bit different, it is much easier to optimise the flow for low drag with a closed car. But for sure the target was to improve the efficiency, though we did not neglect the drag and top speed. In the race you need that peak speed to be able to overtake. At Le Mans, where you are running for 24 hours, cutting drag means you can overtake without stressing the car.'

A modified cooling and fuel tank system was also introduced. 'We had an issue last year with the cooling of the car,' reveals Ulrich Baretzky, head of engine technology at Audi Sport, 'with the intercooler and the water cooler and this was one of the biggest tasks for this year – to modify the car in a way that this problem will not come up again. As an engine man it is frustrating if you make a good engine and the car cannot really make it.'

RULE CHANGES

But, as the engineers in Ingolstadt worked away to solve the problems, the ACO announced a number of significant rule changes, meaning almost all cars had to be heavily revised or granted waivers. 'The regulations came out in November and we had to do a kind of re-set at that time because we were basing our strategy on last year's regulations,' explains Mühlmeier. 'But there were changes and we had to act quickly on them. 'The car was legal when it was running in 2009 but we had to adapt it to the new regulations when they were announced. That was one target. The other was to close the gap [between the Audi and the Peugeot], especially at Le Mans.'

As a result, Audi was forced to completely modify the front section of the R15, which meant major changes downstream. Eventually, the entire shape of the body was revised for maximum efficiency.

It was the rulebook, however, that really defined what the R15+ had to be. 'Most of the changes were forced by the regulations. For example, at the front we had a specific symmetrical profile that the regulations allowed before, but we had to change the trailing edge,' explains Mühlmeier. 'Now it must be three per cent of the length of the profile and the regulation allows a symmetrical profile so we decided to opt for a monoplane symmetrical profile.' The R15's radical channel concept was retained, but much of the internal sculpting had to be removed. Flow to the radiators was revised and flow from the outside of the car was eliminated. Louvres were also added to the rear exits of the car (see panel below left), which appear to do the opposite of what the regulations state, yet Mühlmeier is insistant that they comply.

To be ready with the new car in time for the first race of 2010 Audi Sport made extensive use of its parent company's CFD capability, running Star CD. Later in the project the open-source software OpenFOAM was employed and now Audi Sport is developing it for its own needs. Wind tunnel testing was also employed at both full scale and at 60 per cent.

To help advance development of the new car, the 2009-spec R15s were employed in revised form. 'Some of the test cars are mixes of R15 and R15+ hybrids if you like. The definitive R15+s, such as the one that raced at Paul Ricard, will be all-new chassis,' explains Mühlmeier, continuing, 'Mechanically, the new car is very similar, it is just little things that have been changed.'

> "cutting drag was a clear priority"

BODY RE-MODELLING

Although it is possible to convert an R15 into a R15+, as the chassis itself is near identical, the heavy re-modelling of the body meant it had to be subjected to a new frontal crash test. 'The nose is different. The structures are all essentially the same as before, but the shape is a little different. So we had to test it again.'

Once again, Dallara is a main technical partner of the Audi LMP

VORTEX GENERATORS

The use of vortex generators seems to indicate that conditions are ideal for detached flow on the underside of the Audi's splitter (asymmetrical cross section, 30mm trailing edge thickness). But this should be somewhat expected, considering the reduced height bodywork has made the operating conditions for the splitter a little more difficult, at least as far as the flow off the trailing edge is concerned.

On the previous R15 execution, a lot of work had gone into providing the front wing and flap with ample airflow, allowing for maximum pressure recovery. That is why the covering bodywork was mounted high and shuttered. But the lowering of the front bodywork on the R15+ has simply made ideal pressure recovery for the splitter unachievable.

However, there are whispers that the flow separation is intentional to an extent. Certainly, part of the flow separation is a simple fact of life of the splitter's design and execution. But we understand that there is also a beneficial aspect – the separated flow has less energy, which makes picking up sand and dust and exhausting it directly into the radiators less likely, as long as it is directed to behave in such a manner. The vortex generators simply allow for this entire condition to be better controlled.

Mike Fuller

OPINION: ALLAN MCNISH

In the last session before the race my co-driver, Dindo Capello, said that the Aston was still quicker on the straights – it just got up and went – but it's not all about the straights is it? At the end of the day you have to go round the corner pretty quick as well. I've not yet driven the old car and the new one back to back so it is hard to say how different they are. The downforce doesn't feel that different, but there's certainly a lot less drag.

At the moment, though, we have not got the consistency in the set up. I ran briefly in the initial tests, but the experience we have of the car is quite limited. You can get balance over a short period, but to get it for longer periods is not an easy task and we are not there yet. I think we will do a lot of work up to Le Mans on that consistency.

But it's good to come out of the blocks fighting. The car is obviously quite quick, but we need to understand the car and make it more comfortable to drive and consistent over a race distance. And that will only come with kilometers of testing.

programme, building the tubs and doing other composite work on the R15+ project.

At the heart of the R15+ is a purpose-built diesel engine, which has also been adapted due to the new regulations, which reduce the air restrictors from two 37.9mm restrictors and a maximum supercharging pressure of 2750mbar to a pair of 37.5mm openings at a maximum pressure of 2590mbar.

'Our objective was to keep power loss to a minimum, despite the limitations imposed by the regulations,' explains Baretzky. 'We managed to do that through a lot of detailed work.'

The powerplant continues to deliver more than 440kW (590bhp). 'Just small changes were made, there is no need to make a good engine wrong. If we had made it wrong we would have seen it last year. We must not compare the engine situation with the result last year. All was posed by the aerodynamics and suspension, so we had no real problem about engine power delivery, fuel consumption and so on. That is why we tried to improve a good engine to be a better engine, and to adapt the engine to the new regulations. They meant five per cent less power, so it was a lot of work to win back as much as we have.'

> **"There is no need to make a good engine wrong"**

The evolution version of the Audi R15 TDI completed its roll out on the Audi test track at Neustadt, Germany in early March. The car was then flown to the United States for two weeks of in-depth testing, though even this was not a definitive R15+. Testing was also carried out at Paul Ricard, Monza (skipping the first chicane) and on the twin straights at Eurospeedway.

Before Le Mans in June, Audi will undertake an extensive testing programme on various European race tracks and what it calls 'test races'. The first of these was the 8 Hours of Le Castellet in April, at which the R15+ dominated, beating off opposition from a Peugeot 908 run by the ORECA team. The real proof of all this work, however, will not come until the chequered flag at the end of the longest 24 hours of the year in June.

EXIT LOUVRES

In this rear shot we can see the new legality louvres that cover the rear tyres. Regulation Article 3.4.1b states, 'the rigid bodywork masking the rear tyres must... be designed in such a way that air passing through them is directed toward the ground at the exit.' However, from this picture it would certainly appear that the R15+'s louvres direct the air *up* towards the rear wing at the exit. A further interesting detail is that at their outboard corners, the louvres are inset to just cover the rear tyres, opening up an offset that allows unhindered air to vent out the rear of the wheel wells. The exhausts exit the car similar to those on the standard R15.

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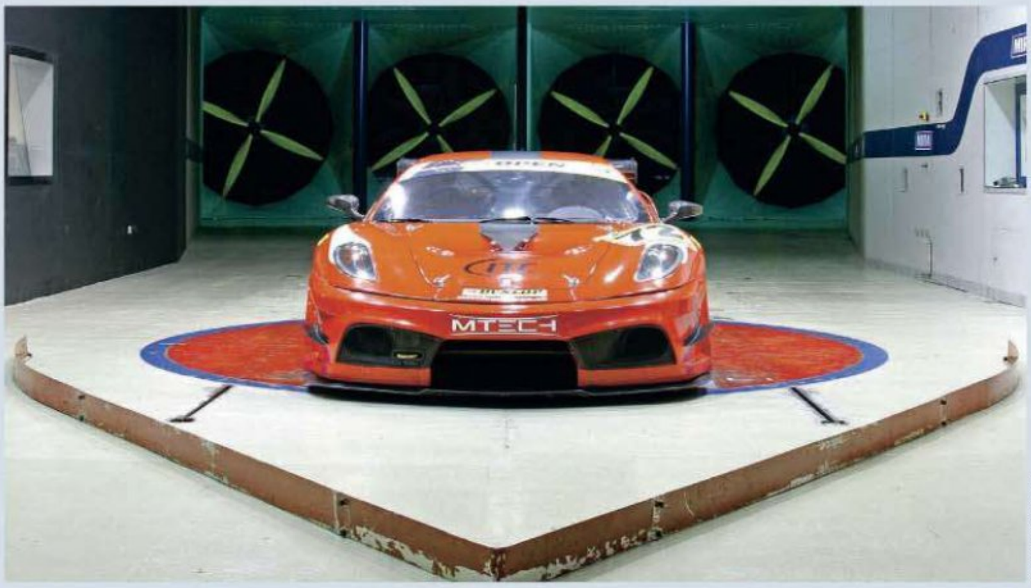
FIRST PRINCIPLES

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

Tuning for balance

This month it's GT3, and a Ferrari F430 Scuderia from the 2009 British GT Championship



Photos: S McBeath

MIRA's boundary layer fence ahead of the MTECH Racing GT3 Ferrari 430 Scuderia

GT3 regulations are pretty restrictive yet, as we see this month, this doesn't mean that a decent level of downforce cannot be generated. Furthermore, although the cars are required to run with their homologated aerodynamics packages, there is still scope for coarse and fine tuning of the front-to-rear aerodynamic balance. This month we'll look at the interesting results obtained when altering front ride height.

BASELINE NUMBERS

Our test car, based on the 2009 model owned by Duncan Cameron and run by MTECH Racing, arrived pretty much as it had finished its last race and the baseline data obtained are shown in table 1.

The roadgoing 430 Scuderia apparently develops 300kg (2943N or 660lb) total downforce at its maximum speed (said to be 198mph). Applying the square law for aerodynamic forces, this would reduce to about 76.5kg (750N or 168lb) at 100mph. Our measurements on the GT3 version of the car equated to a downforce figure of about 2200N (224kg or 493lb) at 100mph, so clearly the level of downforce is significantly more than that of the road car. And although this has obviously raised the drag coefficient into the '0.5' bracket (from probably somewhere in the mid-to-low '0.3' bracket), the aerodynamic efficiency has climbed from what would have been around 0.80 to 1.58 in this configuration, almost double that of the road cars.

It's pretty apparent where this extra downforce has come from. The rear wing, with a 400mm chord and large span, was originally developed for the F550 and subsequently homologated for use on the GT3 430. The car runs a flat floor with a long diffuser, the splitter features 'mini diffusers' set into the splitter ahead of the gaps between the front wheels and the chassis, and ground clearance is down to 50mm under the splitter during our tests. But the car will generate even more downforce out on track because, as we need to remind ourselves when assessing a low ground clearance racecar in the MIRA facility, the tunnel has a fixed floor that inevitably means underbody-generated downforce is underestimated. Nevertheless, the rough comparison with the road car is interesting.

TABLE 1

Baseline aerodynamic coefficients

CD	-CL	-CLfront	-CLrear	% front	-L/D
0.521	0.821	0.348	0.473	42.4	1.58

TABLE 2

The effects of raising the front ride height but *not* the splitter

FRH change, mm	CD	-CL	-CLfront	-CLrear	% front	-L/D
0	0.521	-0.821	-0.348	-0.473	42.39%	-1.58
2	0.522	-0.811	-0.343	-0.468	42.29%	-1.55
4	0.523	-0.824	-0.351	-0.473	42.60%	-1.58
6	0.523	-0.829	-0.357	-0.472	43.06%	-1.59

TABLE 3

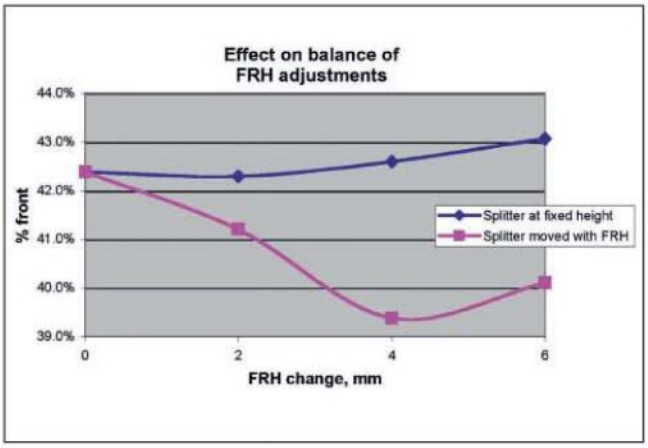
The effects of raising the front ride height *and* the splitter

FRH change, mm	CD	-CL	-CLfront	-CLrear	% front	-L/D
0	0.521	-0.821	-0.348	-0.473	42.39%	-1.58
2	0.521	-0.813	-0.335	-0.478	41.21%	-1.56
4	0.523	-0.805	-0.317	-0.487	39.38%	-1.54
6	0.523	-0.803	-0.322	-0.481	40.10%	-1.54

AERODYNAMIC BALANCE

Figure 1

The effect of front ride height adjustments on aerodynamic balance



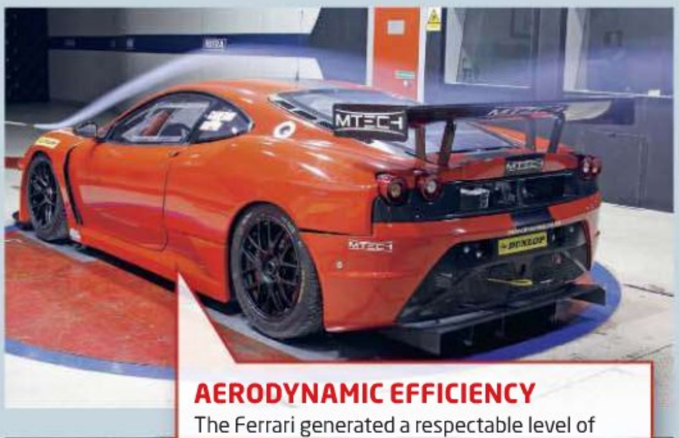
FRONT RIDE HEIGHT

Despite this, we have seen in past Aerobytes that the effects of altering ground clearance and chassis rake can usually be semi-quantitatively assessed at least, so the first thing tried during this session was to raise the front ride height in increments of 2mm, using front tyre shims.

Interestingly, it had been the team's habit when increasing front ride to re-adjust the splitter height back down to its default ground clearance, so for this test this same process was followed. But we also evaluated the same ride height range without re-adjusting the splitter. The results are shown in tables 2 and 3, and the aerodynamic balance shift in each case is plotted in figure 1.

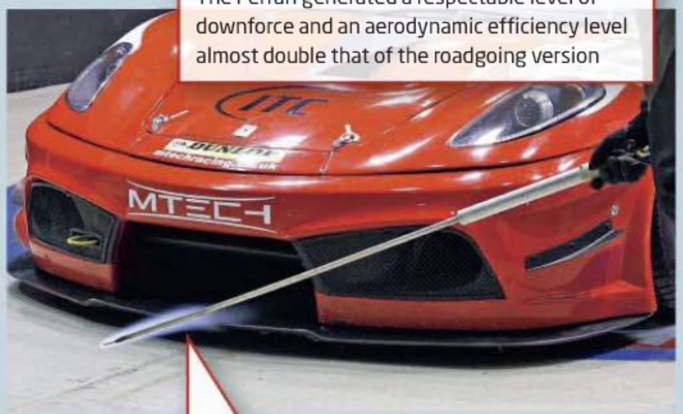
Let's consider first the conventional adjustment in which the splitter moved upwards when the front ride height was raised, as shown by table 3 and the magenta line in figure 1. As the front ride height was raised through the first two increments, the front downforce declined as expected. And the rear downforce increased slightly, again as expected, though this was possibly just the result of the reduction in front downforce and the reduced mechanical leverage arising from the overhang of the splitter ahead of the front axle.

However, as shown in the balance plot in figure 1, when the front ride height was increased by a total of 6mm the initial trend reversed, front downforce increasing again and rear downforce decreasing. This is not what one might ordinarily have expected but, as was suggested by MIRA's senior aerodynamicist Angus Lock, at the lowest ground clearances the 'mini diffusers' may actually have stalled (because of the reduced flow energy in the boundary layer). Then, as the front ride height was increased, the diffusers emerged into more energetic flow, allowing the flow to re-attach in the diffusers, bringing their 'flow augmentation' role into play, and increasing frontal downforce. It is also possible that the fixed floor's boundary layer could have been partly responsible for stalling the diffusers, so this effect may not occur on track. The important lesson here is that we cannot assume that trends shown by low ground clearance devices in a fixed floor tunnel will necessarily mirror reality.



AERODYNAMIC EFFICIENCY

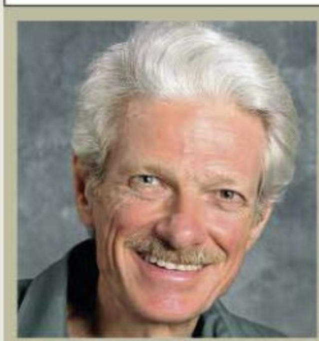
The Ferrari generated a respectable level of downforce and an aerodynamic efficiency level almost double that of the roadgoing version



RIDE HEIGHT ADJUSTMENT

Front ride height and splitter height adjustments of just 2mm yielded tangible changes to aerodynamic balance

Consider now the case where the splitter height was re-adjusted down to its default height after each front ride height increment was added. Here we see there were minimal changes in downforce and balance, but a small balance shift to the front as the front ride height was increased. Again, this is the opposite of what one would normally expect but, in this case, it might have arisen because of the increasing effective angle of the splitter underside as the car was raised but the splitter front was adjusted downwards to keep it at a constant height, effectively creating a wide, gently sloping front diffuser. In general though this re-adjustment effectively nullified the usual aerodynamic change of raising the front ride height. This could be helpful in circumstances where, say, an aerodynamic balance shift was not required but where a mechanical grip increase could be achieved by running the suspension geometry in a more favourable regime.



FIRST PRINCIPLES

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The banking at the 1920's vintage circuit at Sitges Terramar in Spain rose to 90 degrees in places...

THIS MONTH:
Q Is it possible to calculate the maximum speed of a racecar in a banked turn?

A Yes, but you must be sure not to ignore real-world factors when doing so

High-speed banks

Q I wonder if you might be able to help answer a question with respect to calculating the maximum speed of a car in a turn of a given radius, coefficient of friction and banking. I found a formula on the internet that is supposed to be useful *(it contains cos theta – mu × sine theta in the denominator, mu = coef of friction)*, but the speed goes infinite at 45 degrees of bank, given a coefficient of friction of one, and I maintain that is wrong. Can you help?

A The equation referred to above by the questioner is:

$v = \sqrt{(rg (\sin\theta + \mu \cos\theta)/(\cos\theta - \mu \sin\theta))}$

where,

v = the maximum possible linear velocity of the car, in ft/sec or M/sec.

r = radius of turn, gravitationally horizontal, in ft or M

g = acceleration of gravity, in ft/sec^2 or M/sec^2

θ = angle of banking, from gravitational horizontal

μ = coefficient of friction

It will be apparent that for μ = one, the denominator goes to zero when θ = 45 degrees, and v becomes undefined.

It is counterintuitive that the car should have no limiting speed if the banking isn't vertical. It doesn't look right, but it is right. However, for a 45-degree banking, it's only true if μ is at least one.

At 45 degrees, what happens is that at 1*g* horizontal centripetal acceleration (aH = 1*g*), no cornering force is required of the tyres. When speed drops below the value corresponding to 1*g* horizontal, the car tries to slide down the banking and the tyres must exert a negative cornering force. As the speed rises above the 1*g* value, the tyres must exert a positive cornering force, and you'd think at some speed their grip limit will be exceeded.

But let's try some numbers, not using the equation, but just plain old trigonometry and our own brains.

μ = 1 is the minimum requirement for the car not to slide down the banking when it is at a standstill.

> "it is counterintuitive that the car should have no limiting speed if the banking isn't vertical"

At $aH = 0$, the normal force on the tyres is $W/(\sqrt{2})$, force down the banking due to gravity is $W/(\sqrt{2})$, and force up the banking is zero.

At $aH = 1g$, the normal force on the tyres is $W/(\sqrt{2}) + W/(\sqrt{2})$, or $(\sqrt{2})W$, force down the banking due to gravity is $W/(\sqrt{2})$, and force up the banking is $W/(\sqrt{2})$.

At $aH = 2g$, the normal force on the tyres is $W/(\sqrt{2}) + (\sqrt{2})W$, or $(3/\sqrt{2})W$, force down the banking due to gravity is $W/(\sqrt{2})$, and force up the banking is $(\sqrt{2})W$ for a required cornering force of $W/(\sqrt{2})$. The car can do that.

At $aH = 4g$, the normal force on the tyres is $W/(\sqrt{2}) + (2\sqrt{2})W$, or $(5/\sqrt{2})W$, force down the banking is still $W/(\sqrt{2})$, and force up the banking is $(2\sqrt{2})W$. The car can do that.

Now we can see the pattern that's emerging. The normal force is always greater than the induced load due to banking by $W/(\sqrt{2})$, and the net force up the banking is always equal to the induced load minus $W/(\sqrt{2})$. So, although the ratio between the cornering force needed and the normal force asymptotically approaches one, it never gets there. So there will be a limiting speed at some point on a 45-degree banking if μ is less than one, but not if it's greater than or equal to one.

The banking angle where there is no upper limiting speed for any μ is vertical. However, there will then be a minimum speed to keep from sliding down. As μ diminishes, that minimum speed approaches infinity.

In fact, I think we can say that when μ = one, there is exactly one banking angle with no minimum or maximum speed. When $\mu < 1$ or $\mu = 1$, any banking angle less than 45 degrees has a maximum speed, and any angle over 45 degrees has a minimum speed. When $\mu > 1$, there will be a band of banking angles around the 45-degree mark with no maximum or minimum.

The AVUS circuit in Berlin, Germany had a 43-degree banked turn, used in the 1959 German Grand Prix shown here

LAT

BACK TO REALITY

All of this of course ignores certain realities of tyre behaviour. μ isn't constant, and we can't just go on adding normal force without failing the tyres. It also ignores the realities of paving such a banking. No race track in the world has such a banking. Talladega is supposed to be 31 degrees, Daytona 30 and Charlotte 23. I have been on the Charlotte banking and it feels like walking on a roof.

If you wanted to pave a banking at 45 degrees, how would you keep the paving machine from sliding down the banking? How would you even grade such a banking? At 23 degrees, it is difficult to keep asphalt smooth. When the sun shines on the banking, the asphalt softens and starts to sag due to its own weight, which is why tracks that are any steeper are generally concrete.

In other words, the problem posed here is theoretical. In the world we actually live and race in, you can't just go faster without limit, on any existing track.

Still, the theoretical physics of such a hypothetical case are interesting. So are the civil engineering aspects. No doubt it can be done, and even has been done, after a fashion.

I have seen very small, very steep, bowl-shaped circular board tracks at fairs, where motorcycles are ridden around at giddy angles. Board tracks for full-sized cars enjoyed brief popularity in the 1920s in the US and some of these were very steep. They didn't age gracefully though. After a few years, boards started coming loose and impaling people, and board tracks were quickly abandoned.

However, if somebody wanted to build a really steeply banked track today, perhaps the board track concept has some ideas to offer. I don't mean the idea of using wood as the material, but perhaps the idea of assembling the track surface out of pieces formed off site, or at least not formed in place. It might be possible to make the surface as pre-cast sections of reinforced concrete deck, for example, and then to move them into place with a crane. These segments could rest on an earthen road bed, or sections could be supported on an above-ground framework. The framework could then incorporate adjustment to smooth out the track surface. Sections could be replaced individually and any cracks between sections left unsealed for drainage.

Rather like the physics of driving on very steep bankings, this is fun to think about, but I don't plan on holding my breath until somebody does it...

"any banking angle less than 45 degrees has a maximum speed, any angle over 45 degrees has a minimum speed"


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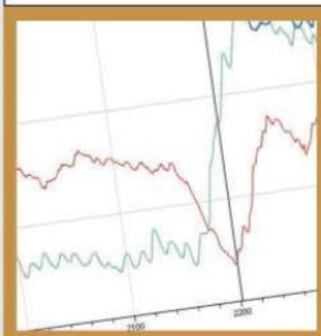


FIRST PRINCIPLES

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

Taking control

How modern technology allows engineers to take more control of the racecar out of the hands of the throttle jockeys

This month we will look at some of the clever tricks that can be employed to make the job of the racecar driver less demanding, with regards to managing the increasing complexity of electronic control systems on modern racecars.

With increasing technology comes increasing amounts of processing power and the flexibility to do more with control systems. 15 years ago a data logger was just that, a system that enabled you to connect a number of sensors, which provided data and possibly some form of instrumentation to the driver. Now, we have control systems that happen to have a data logger included. These allows real-time processing of the information available from the sensors and are able to make decisions based on that. The result is the power enjoyed only by F1 and WRC teams 15 years ago is now attainable by all.

TIME CONTROL

Consider the case of an endurance race, where the race may stretch over a significant portion of a day. Almost all motorsport displays consist of a back-lit dashboard, which in daylight conditions is required to be bright to allow it to be seen when the sun is shining. However, as day turns into night, this brightness can create problems for the driver, so the dash needs to be dimmed down. This can be done through a switch on the dashboard, but a neater solution is to have it automatically vary as the day elapses by employing a real-time clock, either through software or from a GPS device. Taking that idea further, we can map it using a look-up table so the reduction in brightness is controlled as the light conditions change.

STATE CONTROL

Another way of offering control is to have a state machine running for a system. It is possible to define a series of states that provide knowledge of what the vehicle is doing at any particular time. Tying this into the time control mentioned earlier, a simple state machine might be written that enables the position of the car to be known and, as a result of this, to change something.

An example of this is using the rolling lap time and lap

TABLE 1

The four states under discussion

State	Dash display
0	In this case, engine water temperature
1	Previous lap time
2	Fuel level remaining
3	Brake balance

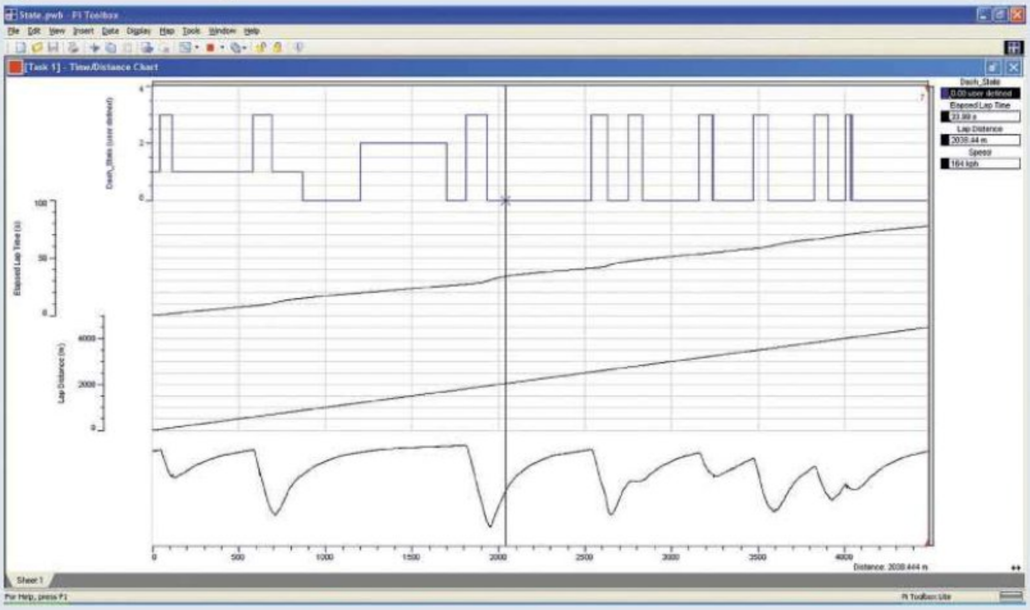


Image 1: data from one race lap, showing the functionality of the on-board sensors in four different states

distance information to change what the driver sees on the dash. Referring back to image 1, we see a lap's worth of data. The channel we are looking at is [Dash_State]. This is defined by the on-board maths as in image 2. This presents four states, which we can then use to show different information on the dash (see table 1 and image 3).

We have done this by using information from sensors and using this so that, for example, when the driver is on a long straight we can take the opportunity to show something useful, such as the fuel level remaining on board, as during this period the driver will have more time to process the information.

DRIVER ENVIRONMENT

With more and more aspects of racecars controlled via outputs on a controller, instead of simple relays, this allows engineers to take the control of more functions away from the driver. For example, closed-cockpit racecars are now required by the rules to keep the cockpit cool – something that can be done either through air conditioning or a driver fan. However, a fan blowing in a driver's face can create a lot of noise when he is speaking on the radio so, as we are controlling the fan, why not link the fan control to the state of the radio?

CONCLUSIONS

A driver's primary job is to drive the car. If we as engineers can decrease the amount of work that has to be done in addition to that then that can only be of benefit to the driver's ability to race. Hopefully, the suggestions made here will stimulate thoughts on how modern control systems can be used to perform functions that normally the driver would have to think about. The less distractions the better, and this might help them decrease the lap time...

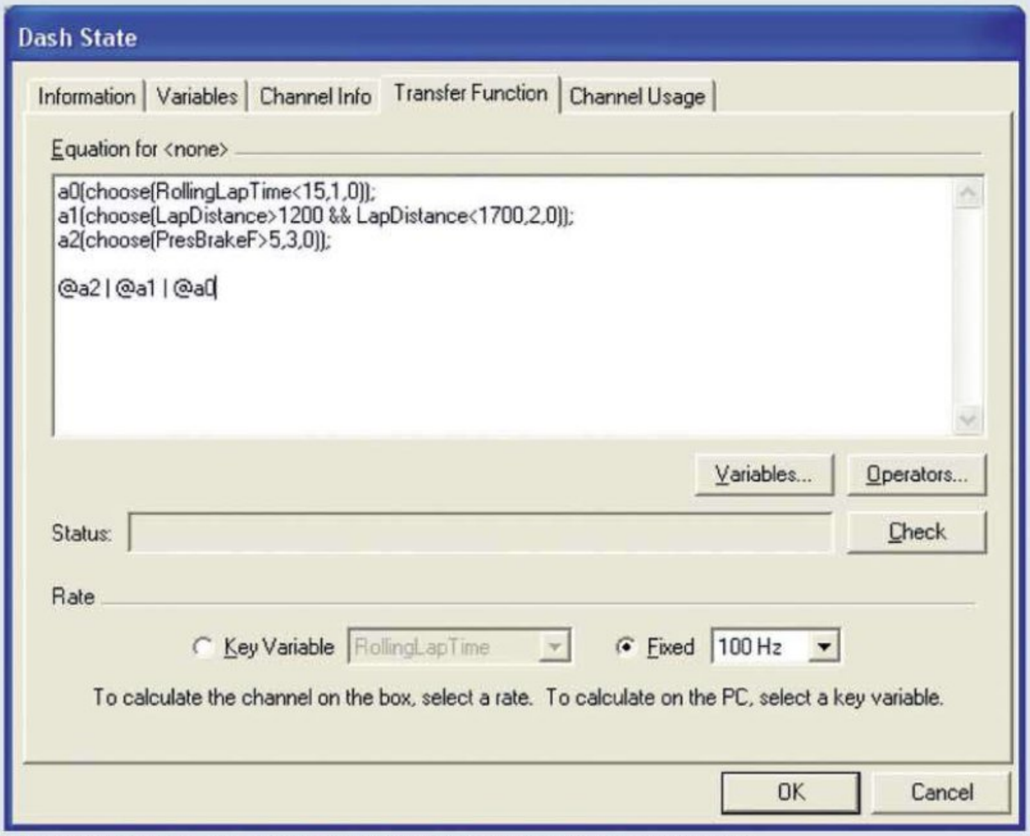


Image 2: the data from the trace overleaf, as defined by the on-board maths channel

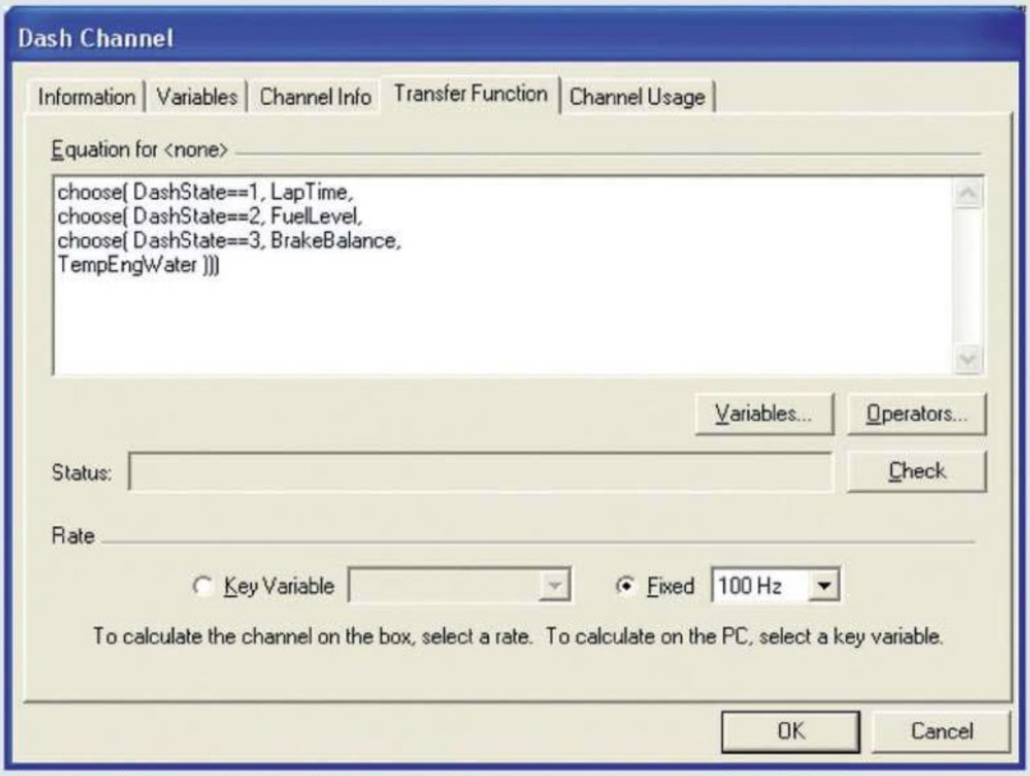
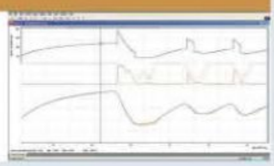


Image 3: examples of the functions that can then be displayed on the dash at appropriate times

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 its data engineers.



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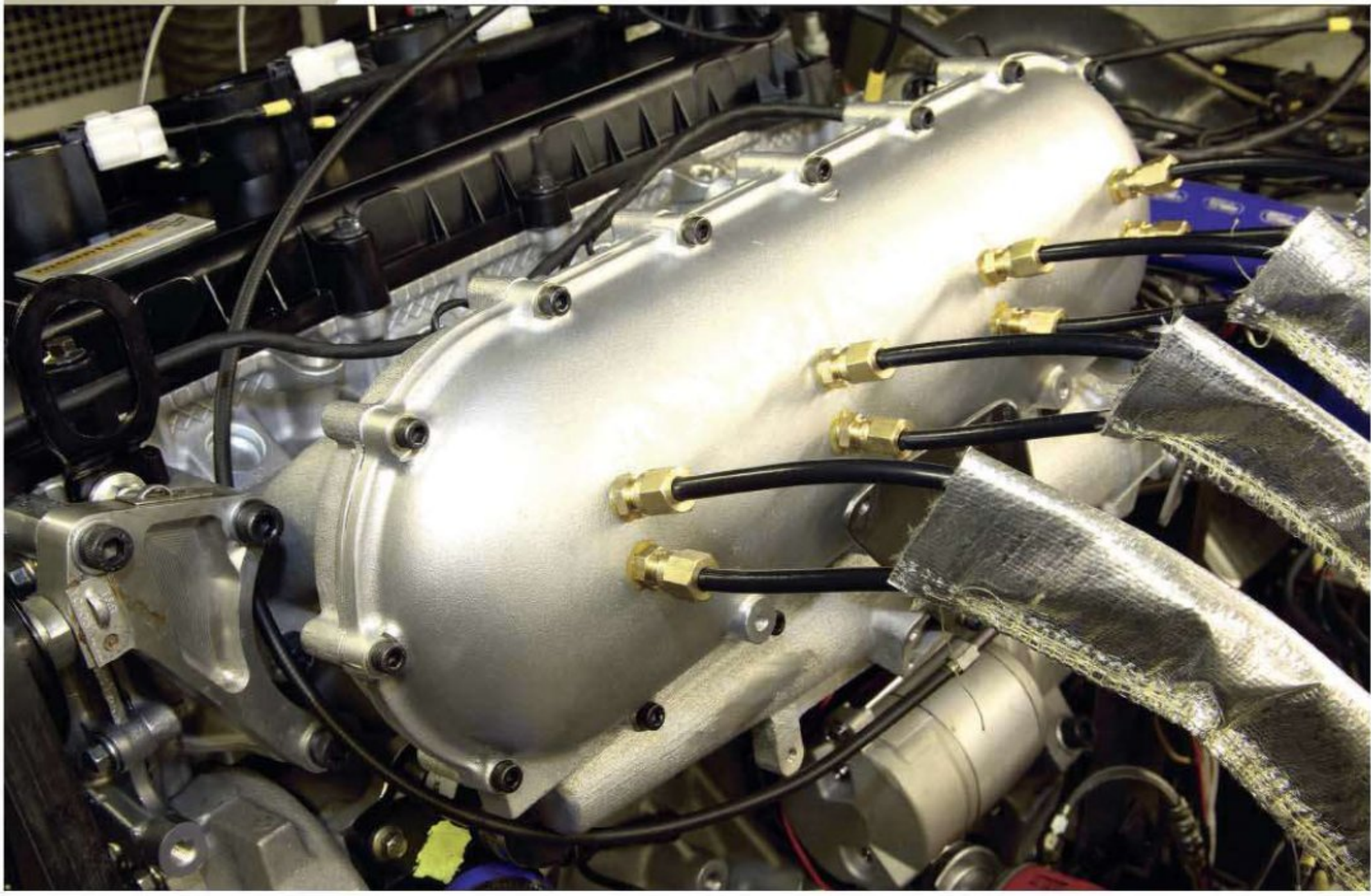


Running on liquid gold?

Forced by changing regulations to consider an alternative method of powering its Ford-based BTTC cars to keep them competitive, Mountune turned to LPG

BY SAM COLLINS

Alternative fuels are often used as a marketing ploy, something to get a sponsor onboard or to get extra media exposure. It is rare for them to be employed for purely performance reasons, but that's exactly what Mountune has done with its new British Touring Car engine, as fitted to the Ford Focus of Arena Motorsport.

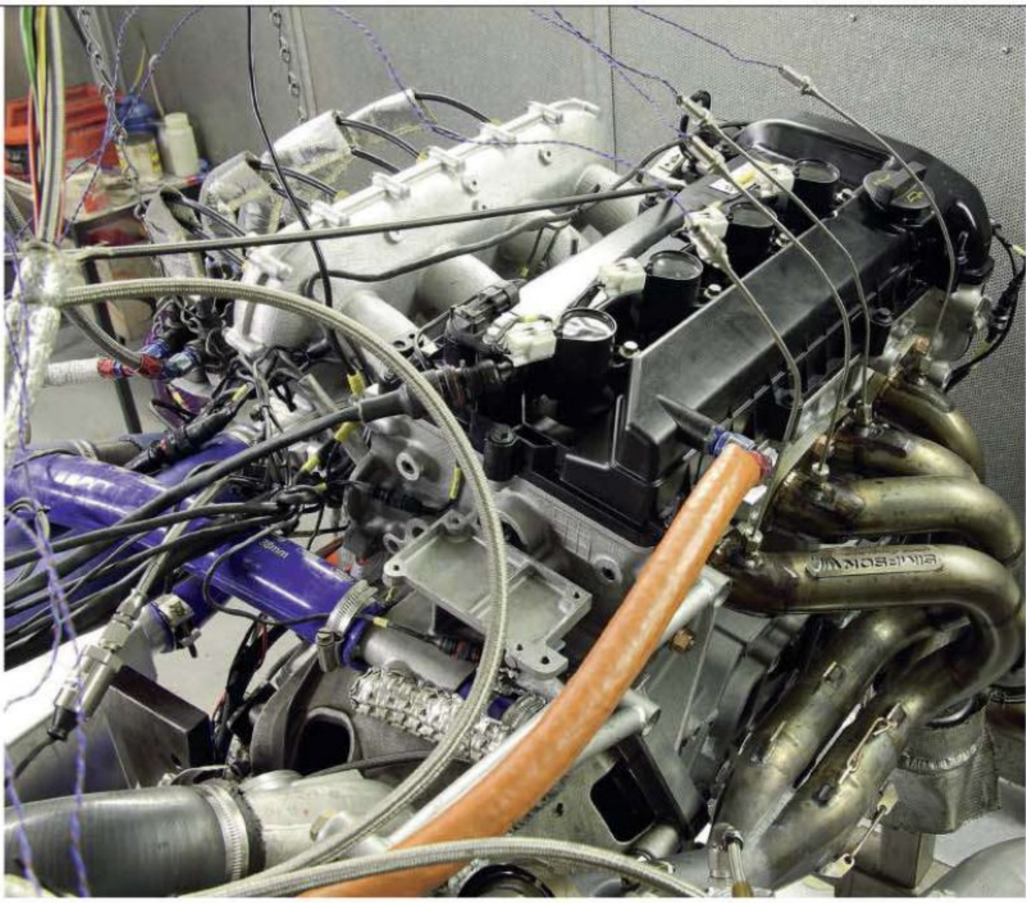
For 2010 the British Touring Car Championship (BTCC) has introduced a new, spec 2.0-litre turbocharged engine as part of its NGTC regulations (more on that next month). 'It became apparent that with the new TOCA NGTC engine coming out, there was no way we would get any Ford support fitting that engine,' explains Dave Mountain, founder of the Essex, England-based engine builder. 'The Ford support is technical not financial, so there was no way forward. We couldn't stay where we were because we probably wouldn't have been competitive.'

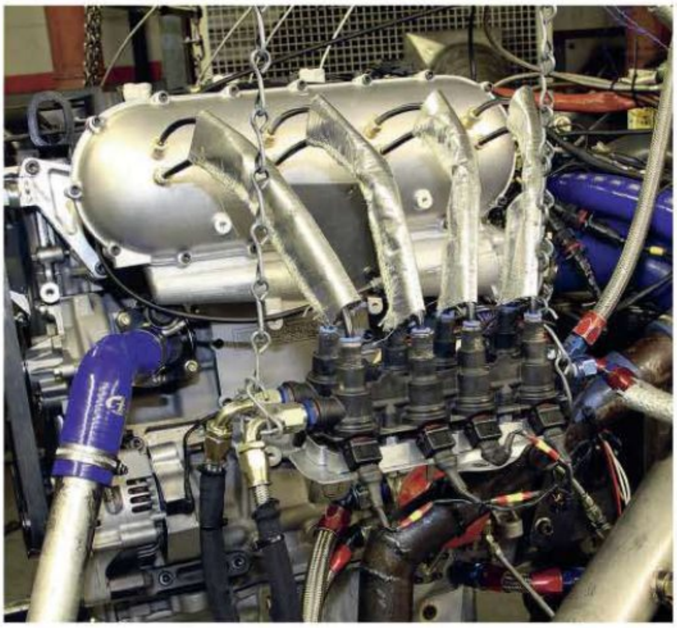
> "everyone was very nervous about the safety aspect"

The turbocharged NGTC engine could, in principal, have better torque than the normally aspirated Super 2000-spec engines used in 2009, and those of teams opting against the new engine for 2010 (series organiser, TOCA, will not allow other petrol turbocharged engines until next year).

However, Liquefied Petroleum Gas (LPG) gave Mountune the way forward it was looking for. 'We worked with TOCA and he formulated the regs. We run the same boost limit (0.8bar) and rpm limit (7000rpm) as the NGTC,' reveals Mountain.

Using LPG fuel was nothing new for Mountune's engineers, as the company has worked with it before on a range of corporate experience and driver development cars used by Palmersport at Bedford Autodrome. It therefore already knew that with LPG-fuelled cars weight is an issue, due to the fuel cell requirements. Although LPG





The difference between 'normal' LPG-fuelled engines and this one is that the charge is injected in as a liquid, not a gas. To maximise the advantages this process offered, Mountune added an extra set of injectors. These are sited in a remote injector block

has a high octane rating, it does not have the same calorific value as petrol, so more fuel is required, therefore increasing the tank size. The tank in the Aon Focus, for example, weighs in at 30kg, making the car around 20kg overweight. 'The tanks have to be pressurised to over 30bar and signed off to a standard, so they are massively over engineered,' explained Mountain. 'We obviously want to get as much weight out [of the car] as possible, but everyone was very nervous about the safety aspect and that is something you have to be aware of. You also have issues like valve seat recession and piston bore wear, because it [LPG] does not have the lubrication properties of petrol. Some people have separate systems, which effectively drop oil into the combustion chambers, but in a racing engine you are only going to do 5000 miles so it is not a problem.

'But on the Palmersport cars we have seen those engines that have done 20-30,000 miles, so you can end up wearing your valve seats out, losing your tappet clearances and then losing compression.'

Whilst Mountune built the Arena Ford engines in 2009, the 2010 spec engines are very different. 'What helped us turn it round so quickly last year when we joined the programme mid-season was the work we did on the S2000 rally engine (see RE V17N6). The big mistake with that project though was that the car just didn't have the mid-range torque, and for rally cars you want good mid-range performance to propel the car out of corners. The work we have done with turbo rally engines though meant we could get LPG working well with the turbocharger fairly quickly. So the only real learning curve we had was the LPG liquid system, which we had never run before. Once we got over the early problems, it has been very good.'

LIQUID INJECTION

The Touring Car engine has a significant difference to the Palmersport units in that it has a liquid injection system, whilst the Bedford cars have gas injection. 'It is very efficient when the liquid turns to gas as there is a big cooling effect. It also simplifies the system as you don't need an evaporator, which is quite a big, heavy thing,' reasons Mountain. 'We started off with the injectors fairly close to the inlet port as it evaporates

"It is very efficient when the liquid turns to gas as there is a big cooling effect"

pretty much straight away but, because it was so close to the cylinder head, we think we were getting part-liquid, part-gas going into the cylinders. We were getting a very strange pick-up problem around the top ring, which is unusual, and we think it was a super cooling effect. It's unusual because it was the opposite of what you usually get. So we gave it more time to evaporate and that seems to have cured the problem.'

The cylinder head is therefore fitted with two injectors per cylinder to get sufficient fuel to the combustion chamber. 'We were pushing the boundaries in injecting liquid. To us it looked like a technical advantage and we wanted to go that way. It was a big risk, but I am sure now it has been the right decision. The injectors actually run remote from the manifold, then there is a short pipe that comes from the injector to the plenum. We have in fact placed that injector block in front of the radiator so it gets some warm air to prevent these


Lawrence Butcher

After a few early teething problems were sorted, the LPG cars proved faster than the petrol cars on the straights

TECH SPEC

BTCC FORD FOCUS

Engine: 2.0-litre Ford Duratec, built and prepared by Mountune Racing

Power: 300+bhp at 7000rpm

Torque: 300+Nm

Bore: 87.5mm

Stroke: 83.1mm

Turbo: Garrett GT28 roller bearing

Valves: 35mm inlet 30mm exhaust 5.5mm stem diameter

problems. You have to be careful and we have tried to get some hot air over the system. The injectors are side fed because if you use an end-feed injector the needle struggles to open and shut and control the fuel as the pressures are quite high. Also you have to try not to put too much heat into the liquid through the injector.'

As you might expect, starting the engine is not as straightforward as with the petrol units,' as Mountain explains: 'With road car conversions you usually have a system where you start the cars on petrol and then switch over to gas. That's because LPG doesn't ignite at very cold temperatures. With racing we don't need that, but when you listen to the racecars they don't fire up instantly, even though they are pre-heated. You have to crank them and crank them and eventually they fire.'

TECHNICAL PARTNERS

Mountune and Arena had a number of partners and official suppliers on the Ford project, including Prins, Calor and Millers Oils. The fuel injection system was supplied by one of those partners, Prins. 'It is a marketing and technical project for them,' explains Mountain. 'Calor have been brilliant because, from our point of view, we are geared up to fuel up with petrol, so Calor have put up all the pumps and procedures. Whilst it is a standard fuel we use, they make sure it is as purified as it can be. For standard road usage, it is 95 per cent pure, and we are running at 98 per cent. Refuelling the car at the moment is a case of dropping the tank, filling it up on a set of scales so they can see how much is going in and then re-fitting the tank to the car.'

With LPG fuel there are a number of further considerations beyond refuelling and supply, as Mountain explains: 'Combustion temperatures tend to be a bit lower because of the cooling effect you get when it evaporates. It is almost like having a big intercooler. The exhaust temperatures seem to be that little bit lower too, compared to what we were seeing on petrol. The heat transfer is still similar though. We haven't been testing in any high ambient temperatures, so we haven't been able to prove whether we can run a smaller radiator yet. Logically, we should be able to, but what we don't want to be is marginal on cooling. One of the problems is that we have had to homologate a lot of this stuff and we have not done a lot of testing. Now there are some jokers that can be applied for, so if there is something we find that can be an advantage we can do it.'

The engine's components, like most Touring Car and GT projects, lie somewhere between tuned OE and purpose built racing engine. 'The cylinder block is production. As the boost levels are fairly low we can run with it. They are only about 1.8bar absolute, so 0.8 bar of boost,' continues Mountain. 'But con rods, pistons, crankshaft, all of that has changed. For the first time as a company we are using CP pistons. We were up against it and they seemed to be out to impress us and made some pistons very quickly. The rods are Arrow [Precision], as is the crank. Because we were quite conservative, it is rock solid. Possibly we could have saved a few grams off the crank and rods, but what we wanted was reliability. It is a low revving engine, it only sees 7000rpm, so there is not a lot to be gained out of taking any big risks.

> **"we were quite conservative... what we wanted was reliability"**

The valve size is totally standard, but the material is obviously improved. The head is fully ported but, unlike the naturally aspirated engines, we don't do big ports, we just do some work around the bowl area and the valve seat to tidy it up. Being forced induction you don't need to run hulking great ports. The port diameter remains standard, so you get good air speed and driveability. We use Supertech valves and they hold an awful lot of Duratec stuff on the shelves. We have really struggled in the UK to get a really good valve supplier. Then we use Kaufmann springs, which are a very expensive spring, but you just fit them and forget about them. The camshaft is designed by us and ground by Piper, but is nothing really radical. The valve lift is limited to 11mm by the regs and, being a turbocharged engine, you can run pretty short periods, as we are doing. It is conservative. The real learning curve was getting the LPG to work properly. To begin with we thought were in for some serious trouble, but it worked out well.'

In fact, it possibly worked out too well as, following the pre-season group test at Brands Hatch, some teams complained that the LPG fuel gave the Arena cars an advantage as they were clearly quickest down the straights. For the minute it seems the team may have found an advantage, but it remains to be seen how long this lasts and whether TOCA will decide to further restrict the LPG cars as this season progresses.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Grinding back the gears

© Peter Sjökvist | dreamstime.com

Millers Oils claims it has come up with the next generation of motorsport lubricants

While all attention on an exciting and busy 2009 British Touring Car Championship was firmly centred on the tussle for the crown between Colin Turkington and Jason Plato, a small but significant shift in motorsport oil and lubrication technology was taking place up and down the BTCC pit lane.

Throughout the course of the season, six of the 12 competing teams, including the Carbon Zero Racing team and Team AON, used a revolutionary new transmission oil technology from motorsport oils and lubricant specialist, Millers Oils. The Nano Technology range, launched in January 2009, enjoyed a remarkable first year, exceeding the expectations of all involved in the development of the products, and went on to provide the experienced Millers Oils technical team with substantial successes, on and off the racetrack.

WEAR AND TEAR

The main problem that faces race engineers with transmission systems is coping with and managing the high level of wear and tear gearboxes suffer under racing conditions.

To this point, the oils and lubricants used have often been designed to reduce and contain the problem, with many teams being advised to use oils with high viscosity and temperature characteristics – not too viscous at low temperature, but adequate viscosity at high temperature – to protect the highly loaded gears. However, in many conventional lubricants, as the system temperature rises the oil's sensitivity to heat quickly reduces its ability to manage the effects of heavy loading and shock loading, damaging its overall efficiency and producing a secondary effect of initiating the oxidation process.

> **New developments in engineered particles has gathered pace over recent years**

The chosen oil also can also often be susceptible to shearing from the non-stop and often violent action of the gear systems. This interaction between two gear parts often leads to the oil being pushed out and away from the section it needs to lubricate.

These constant factors of changing operational temperatures and unpredictable rates of wear place great pressures on the oils chosen, and it is this inherent problem Millers Oils set out to address.

Martyn Mann, technical director at the West Yorkshire-based company takes up the story: 'Over the last two and a half years, a suitable alternative additive system had been sought to replace the existing Millers Oils' CRX range of competition gears oils. A complete upgrade had taken place on the engine oil range of motorsport products several years previously. With the incorporation of triple esters, we discovered that the previous range of gear oils relied on a two-pack system that provided chemical and physical barriers within the gearbox.

'The important objective for these new gear lubricants was that the products had to be better than our current range, offering additional benefits to users. With this in mind, we set out to find the best gear lubrication possible, which we hoped would bring long-term benefits such as improved component longevity.

'Conventional wisdom suggested that we turn to using solid lubricants, which were more resistant to higher temperatures, with a thickness that could help abate problems with gearbox friction. But when some of the early nano options we found were investigated, it became clear that incorporating this technology into driveline products would offer a distinct advantage. New developments in engineered particles has gathered pace over recent years, and this has meant that oils can be customised to fit many different applications, with a flexible and adaptable range of differing shapes and sizes.'

This new technology offered the Millers Oils' team all the necessary requirements for a new range of oils that would improve upon what was already available. Mann: 'Our main parameters were that the finished products should be able to transmit the required power reliably, be effective in lowering transmission losses through minimal friction and, as a result, lower overall lubricant temperature as well.

'The nano particle chosen actually resembles ball bearings and falls into the size range 40-100 nanometers. The particles, when viewed under a scanning electron microscope, appear as 'onion'-type shapes consisting of nested or concentric spheres.

'Initial contact with potential suppliers of nano components revealed that, while it was still early days for mass production to be feasible, some material was available in limited quantities. 'Luckily, we eventually sourced a supplier that was able to provide commercially available amounts that we could work with.'

Mann and his team found that the comparison of existing technology to a similar viscosity product using the nano components provided a significant coefficient of friction reduction. 'We were impressed with what we found and pleased with the initial test results. In a back-to-back comparison we ran two fluids on a standard lubricants test to measure a four ball contact scar diameter, which had run in the fluid for one hour. The fluid using the nano technology showed a 50 per cent improvement. Once this discovery had been verified, the project could move forward, and a new series of fluids were formulated to cover a wide range of applications and viscosities.'

NANO TECHNOLOGY

The science is based on the chemical behaviour of extremely minute particles - a new family of additives - known as Inorganic Fullerines (IF), which are made up of structures the size of 100 nanometres or less. What these nano particles add to the overall

LAT

On-track testing in the BTCC showed a marked reduction in component wear

lubricant regime is a special layer of ball bearing-shaped particle structures. Under light loads these particles work just as ball bearings would but, under higher loads and shock conditions - as found in a racecar transmission system - the particle starts to deform and then acts as a roller. Under yet more extreme conditions, the 'skins' of the concentric particles start to break apart in a similar way to chemical Extreme Pressure (EP) additives, depleting when they respond to temperature-sensitive conditions. However, unlike conventional EP additives, the nano particles are inert and operate under all temperature conditions, which gives a wider spread of protection. Mann and his team also found evidence that metallurgical issues, such as micro-pitting, can be alleviated with this type of additive system, as can potential weaknesses in compact transmissions that are close to reaching capacity.

The upshot is that the technology reinforces the oil molecules, which has the key advantage of reducing friction, heat and wear in transmission components. In extreme racing conditions, Miller Oils' new nano technology oils were shown to considerably improve performance over oils that used more 'conventional' solid lubricants, with reductions in friction of up to 25 per cent being regularly recorded in tests.

> "the nano particles are inert and operate under all temperature conditions"

ON TO THE GRID

During the course of the 2009 season, a pattern started to build, with feedback such as 'durability has improved', 'parts replacement is reduced' and 'gearbox cleanliness is much better', being consistently received from team engineers up and down the racing paddock.

Alan Cole, team manager of Arena International / Team AON, racing with the returning Ford marque during 2009, noted that 'the CRX 75w90NT gear oil helps to prevent overheating issues and produces very little dog damage. Before using NT gear oil, we would expect to change two dog rings per weekend, now we only change one every two races, so this is a very helpful improvement.'

This praise was echoed by team principal at TH Motorsport, Trevor Humphrey: 'It seems to cope with the heat much better than any other gear oil we have used, and retains its viscosity far longer. The oil seems to stick to the gears and dog rings much better and, by the time we approached the half-way point in the season, we had only spent about half of what we spent the previous year on replacement gearbox parts.'

Mann concludes: 'From the research to the reality in developing the nano technology oils, we have been quietly confident that we had struck upon something radical and important. The success we enjoyed in 2009 helped to prove this. The use of nano particles is still in its early stages, but with the Millers Oils' nano technology (NT) CRX range now under our belt and up and running, we are already conducting the research on further oil and lubrication applications for this type of technology. It is Millers Oils' intention to apply friction-reduction techniques to improve the problem of engine power loss in the areas of the engine systems where up to 25-35 per cent of frictional losses occur, such as piston rings and liners.

'We know that, in total, the energy loss from an engine can exceed 50 per cent,' Mann concludes, 'and that increases with engine speed to far higher figures, so there is great scope for us to develop solutions that will improve these numbers. Millers Oils will seek suitable partners to develop nano technology products further into crankcase formulations, along with other areas such as wind turbine gearboxes.'

TECH SPEC

CRX75w90NT - TYPICAL CHARACTERISTICS

SAE viscosity grade:	75w90
Specific gravity at 15degC:	0.897
Kinematic viscosity at 100degC:	17.3cSt
Kinematic Viscosity at 40degC:	n/a
Viscosity index:	n/a
Pour point (degC):	n/a
Brookfield viscosity at -40degC:	88,000 mPas

Re-evaluating the results

Further work on rear wing end plates has clarified a number of different issues

LAT

BY SIMON MCBEATH

Conventional wisdom has it that deeper rear wing end plates are better than shallow ones. It turns out this may depend on what aspect of aerodynamic performance you want to optimise, but our continuing investigations into the subject have produced some valuable lessons, not all of them aerodynamic in nature...

Racecar Engineering V18N8 featured a CFD exercise carried out by your writer in which variations to rear wing end plate depth yielded some surprising results. The downforce and drag results did not fit the expected patterns, and instead seemed to suggest that some shallow end plate depths produced more downforce than deeper ones. The article prompted two undergraduate students in the UK to make contact about undertaking their own final year projects on this same topic, and wing models were provided to them for the purpose. Their findings, in turn, prompted the writer to re-run his own evaluations, and some rather different results to those original ones emerged. This article will attempt to set the record straight and, at the same time, share the lessons learned, not just the aerodynamic ones but also the lessons about going back and double checking unexpected results, about not putting excessive trust in CFD results, and also about the potential vagaries of simulation tools that can catch out the unwary user.

First though, let's briefly re-cap the original project details. A single element wing was 'fitted' with varying depth end plates to investigate, using Ansys FloWizard CFD software, the effects on downforce and drag. The depth of end plate below the lowest part of the wing's lower surface was the only parameter varied in the CAD models. The amount of end plate above, in front of and behind the wing was kept constant in all cases (see figure 1). An initial set of five runs produced an anomalous-looking result, with downforce higher than expected at one of the shallower end plate depths (see figure 2). So more models

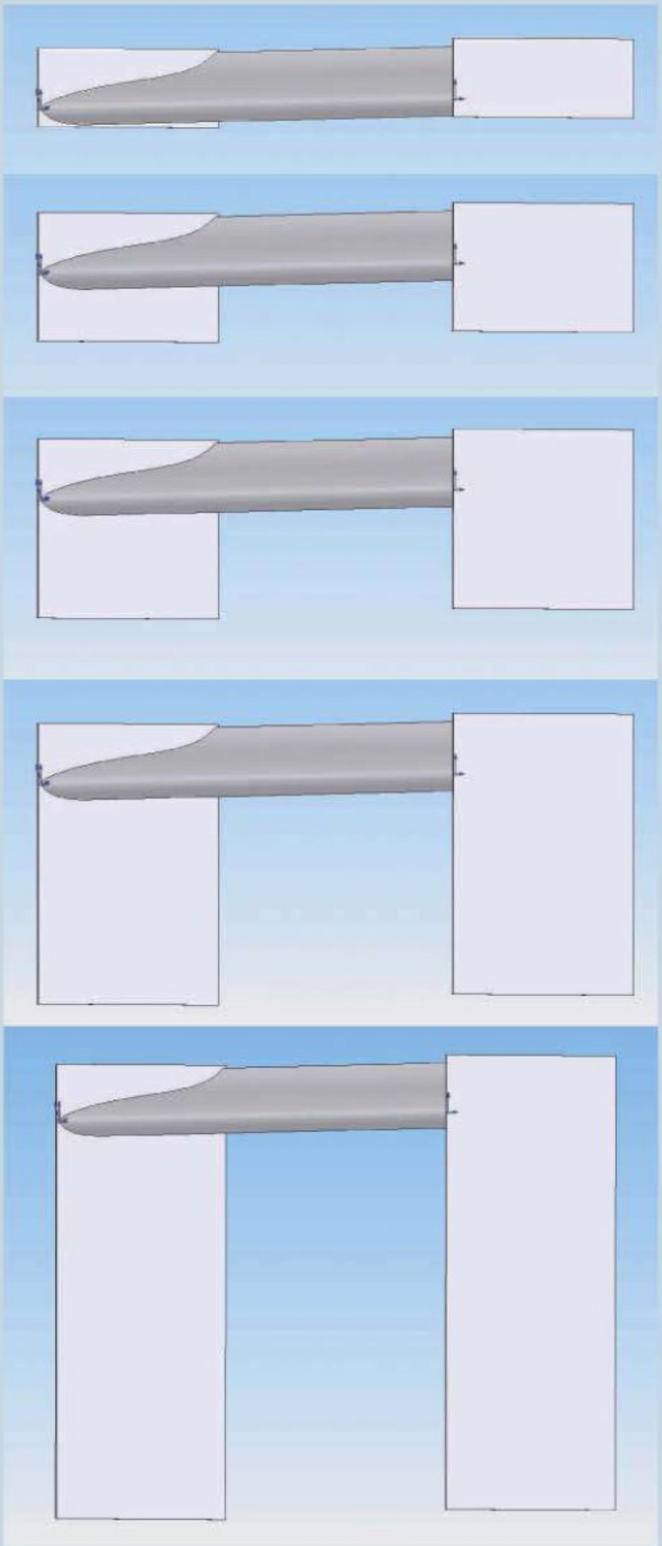
with end plate depths either side of this were constructed and run in the CFD, producing yet more anomalous results (as shown in figure 3). However, the data were seemingly reinforced by the pressure and velocity distributions, and this led your writer to the conclusion that something interesting might have been found that would warrant further investigation in applications where end plate depth could be varied within technical regulations.

Subsequent to the original article's publication Daniel

THE PROFILES

Figure 1

Five of the end plate depths evaluated, showing the overall range tested



Byrne at the University of Central Lancashire (UCLAN) and Chris Lewis at Oxford Brookes University indicated their interest in carrying out follow-up work on this topic. Each wanted to take a slightly different approach, but during the course of their projects each was to investigate varying the same parameter on the same wing profile using CFD. And although each student's work did indeed suggest an exploitable area of the drag curve in a way that does not seem to have been widely published, the irregular anomalies originally found by the writer were not replicated (see figures 4 to 6).

With the benefit of hindsight of course, this irregularity itself was a clue that something was not right with that original data. Indeed, Dr Dave Petty, a senior aerodynamics lecturer at Kingston University, having seen the original article, made contact to say, essentially, that 'there must be a problem with the CFD, the fluctuations are too big to be real.' The only thing to do then at this point was to re-examine the models and methods to see if the anomalies repeated themselves or not. Or, as my chemistry teacher used to say when her classroom demonstrations went awry, 'let's see if we can produce a better set of results...'

ANOMALOUS RESULTS

Figure 2

The original plot of the first five CFD runs (all forces given were at 100mph unless otherwise stated)

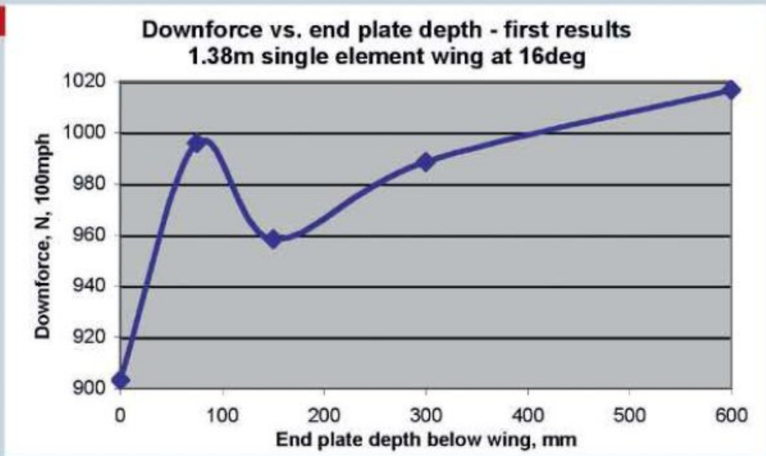
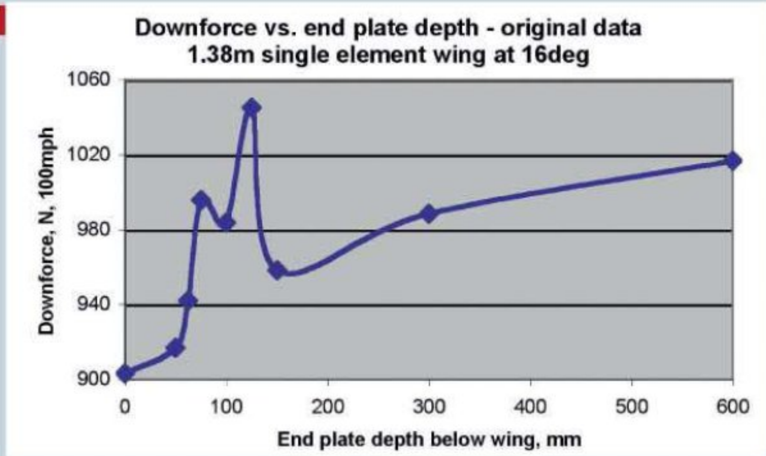


Figure 3

The original plot of the whole set of CFD runs



REPEATS

So a larger set of end plate depths was constructed, in 25mm increments from 25mm up to 200mm, 50mm increments up to 300mm and 100mm increments to 600mm depth, covering the maximum likely practical range of rear wing end plates that might be seen on 'mainstream' racecars. And the same wing was used, this being one of the writer's single element designs that has been used in various applications. The one thing that had changed this time was that Ansys UK had kindly made the latest version of FloWizard CFD software, version 3.1.8, available. (Note to readers: now that Ansys v12 has been released, FloWizard has become a 'legacy product', meaning Ansys will not be selling it any longer).

So as before, each model in turn was run in this latest software using default settings for mesh quality, and accuracy vs speed. Very early on it became apparent that the new version of the software was not 'behaving' as its predecessor had done. Different cases were running to apparent 'convergence' (when the software decides a solution has been found and automatically stops) after quite different numbers of solver iterations, and the results were equally obviously not fitting the expected pattern. But unlike the previous project, where the variations were not wildly different from the expected values, this time the initial values were much lower than expected. However, FloWizard includes an option to 'continue calculation', and it proved necessary to invoke this option a number of times in each case to obtain results that properly converged. Figure 7 shows the solution history of one fairly typical case, this requiring 'continue calculation' to be selected a dozen times before the downforce (and drag) values had clearly reached a plateau. Each point on the curve represents a point at which FloWizard stopped and indicated convergence had occurred. The drag values showed a similar pattern to the downforce values.

> **"beware of putting excessive trust in the results of numerical simulations"**

All the cases run in this second set of trials needed manually nudging along until the results had definitely and clearly reached a plateau, with anything from two nudges to 19 (in two cases) being required. On average, just over 10 nudges were needed to achieve a mean of just fewer than 383 iterations to ensure the results had reached a plateau. Leaving aside for a moment the possible reasons for this manual intervention being necessary, its occurrence provoked two thoughts. Firstly, that the irregularities in the results in the original work may have arisen because of something similar happening with the earlier version of FloWizard. And secondly, that although it perhaps should have been apparent that those original cases might not have properly converged, there was no obvious indication that this may have been the case. The moral here is likewise twofold: check spurious-looking results, and beware of putting excessive trust in the results of numerical simulations.

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So why did it prove necessary for these cases to be manually nudged to ensure they had fully converged to reliable solutions? And could this apparent inability of the software to converge at the first attempt be an explanation for the irregular results found in the first trial? Whatever the specifics might have been in this case, the words of an aerodynamicist friend with broad experience of numerical and physical test methods offer a more general caution: 'Interpretation of CFD is still a major grey area, despite the apparent availability of all the numbers and fancy graphics. It's too easy to believe what you see. And 'pure' CFD people are often the most trusting of all, despite knowing its inner workings intricately. If it's any consolation I've run cases multiple times and, without changing a thing, got different answers.' So the rest of us need to be wary, and clearly not just when we encounter deviations from expected trends.

THE BETTER SET OF RESULTS

Whatever CFD vagaries might have contributed to those original irregular-looking results, and whatever level of naïvety your writer displayed in accepting them as reliable, the latest set of results, having been pushed along until they had clearly reached a plateau in each case, would seem to paint a clearer picture of the relationship between end plate depth and wing performance, and the results are shown in figures 8 and 9. Now we have a considerably less bumpy plot depicting, in the case of downforce, more or less the expected pattern with increasing end plate depth, in general agreement with the students' data in figures 4 and 6.

There is still some interesting bumpiness in the 125mm to 250mm end plate depth range in the writer's data, which may or may not be real, and this would undoubtedly be better examined further with wind tunnel trials. Furthermore, the curve seems to imply that downforce would continue rising with increasing end plate depth, the results from 300mm to 600mm being on an essentially linear, upward slope. Perhaps wind tunnel testing would be a more reliable method of validating this too, since it might have been expected that the gains would level out.

Drag, however, seems to follow an interesting and potentially exploitable pattern. Again the curve in figure 9 shows some bumpiness, but in essence there is a drag minimum in the 200mm to 300mm end plate depth range indicated here with this wing. The minimum value is at 250mm and it is, for example, 2.6 per cent lower than the drag level with 50mm of end plate protruding below the wing's lower surface. Although this would provide a smaller proportional reduction to whole car drag, it could still represent a worthwhile increment if technical regulations allowed an appropriate degree of freedom. Interestingly, the plots in figures 5 and 6 obtained by the two students who followed up on

NEW RESULTS

Figure 4
Downforce plot obtained by Chris Lewis at Oxford Brookes University

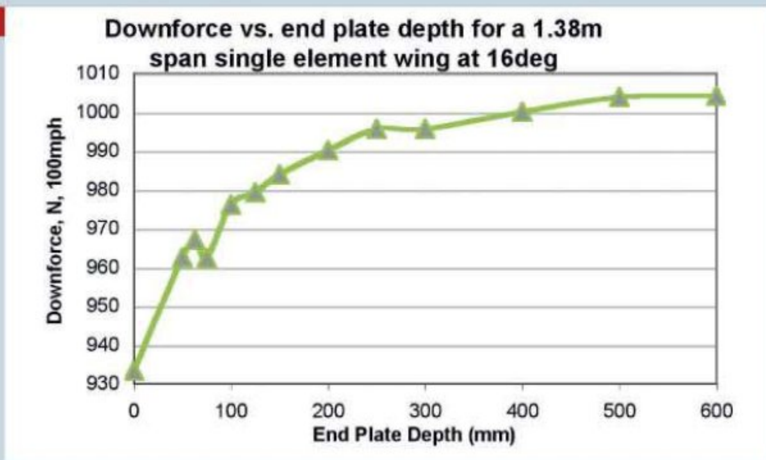


Figure 5
Drag plot obtained by Chris Lewis at Oxford Brookes University

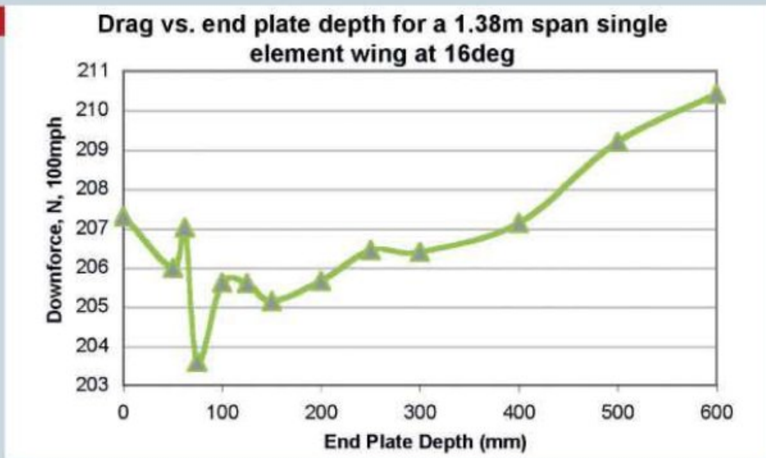
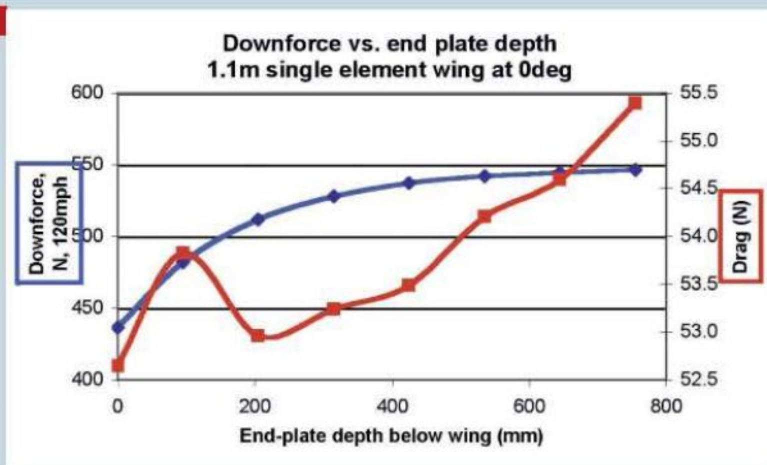


Figure 6
Downforce and drag plots obtained by Daniel Byrne at University of Central Lancashire. Note the different wingspan and angle of attack (velocity was 120mph, or 53.8m/s)



the original project show a similar generic pattern, with a drag minimum somewhere in the 150mm to 250m region, depending on how your eye filters out the bumps. (Again, wind tunnel studies might be the only way to see if these bumps are real or the result of something in the simulations).

At greater end plate depths there seems little doubt from these latest results (including those of the students) that drag then rises as end plate depth is increased. The bigger end plates themselves generate additional frontal area, and hence increased pressure drag, as well as greater 'wetted' surface area, and hence increased skin friction (viscous) drag. It would therefore appear that the combination of these additional drag increments is overcoming the reduction in vortex drag from the deeper end plates in this case. In terms of the drag reduction from deeper end plates, it seems deeper is better, but only up to a point. Once more, wind tunnel follow-up tests would confirm whether this assertion is valid.

If the downforce and drag numbers are combined into an end plate depth vs downforce over drag (-L/D) plot, as in figure 10, it can be seen that, by this measure of efficiency, performance apparently peaks at 400mm end plate depth, but good performance can be had from 200mm and upwards.

So in cases where technical regulations allow a choice of end plate depth, that choice could, as usual, be made on the basis of maximum downforce, minimum drag or best -L/D, with the optimum solution, as you would expect, being different in each case. A useful point to finish on then is that in spite of the seemingly erroneous data reported in that original article in V18N8, there does seem to be benefit to be had from optimising end plate depth to match the needs of the application. Now it remains to get this project into the wind tunnel.

Thanks once more to Ansys UK for the use of FloWizard, and to Daniel Byrne and Chris Lewis for sharing their final year project

CONVERGENT RESULTS

Figure 7

'Manual nudging' was needed to get solutions to fully and clearly converge using default settings in FloWizard 3.1.8

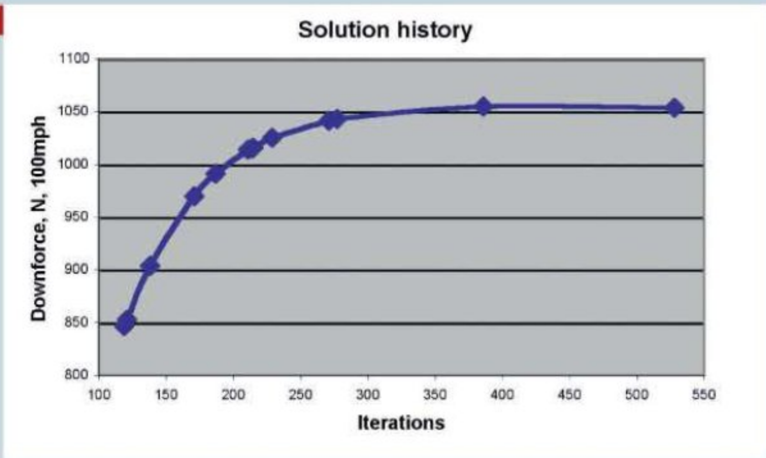


Figure 8

Results from (hopefully) fully converged CFD runs show more or less the expected relationship between downforce and end plate depth

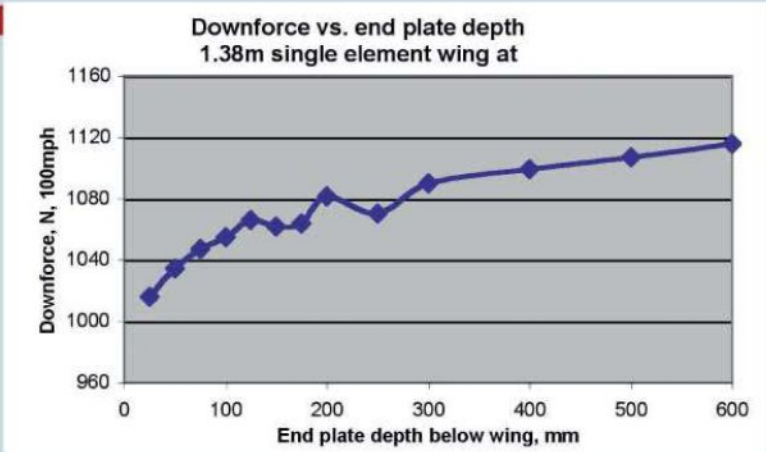


Figure 9

Drag results show a trough centred at 250mm end plate depth in this case, with drag rising thereafter

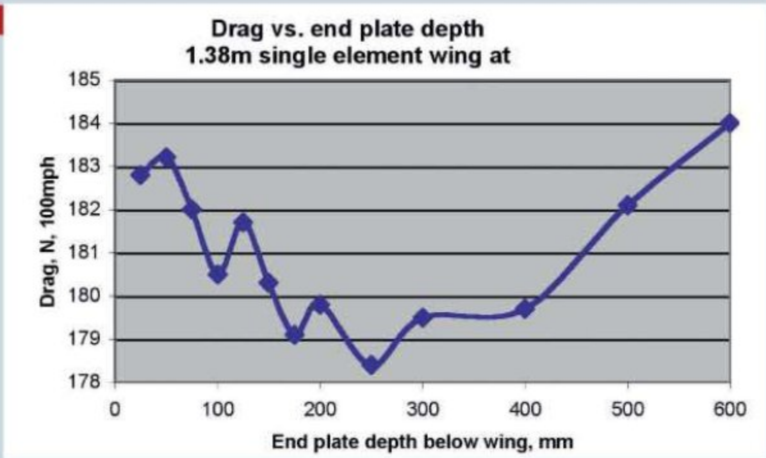
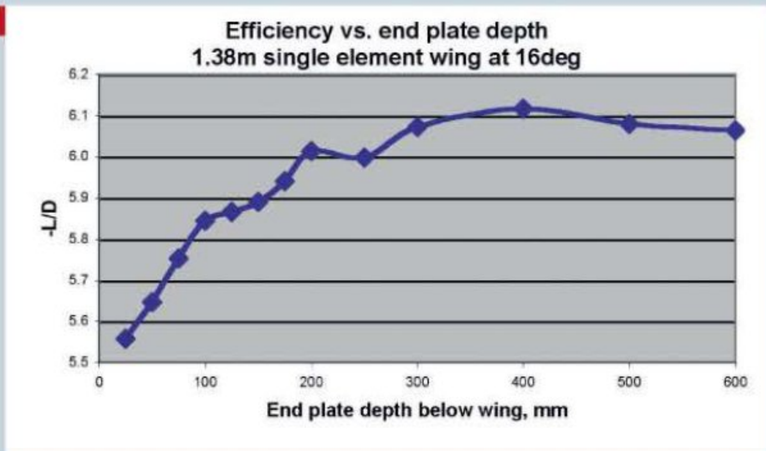
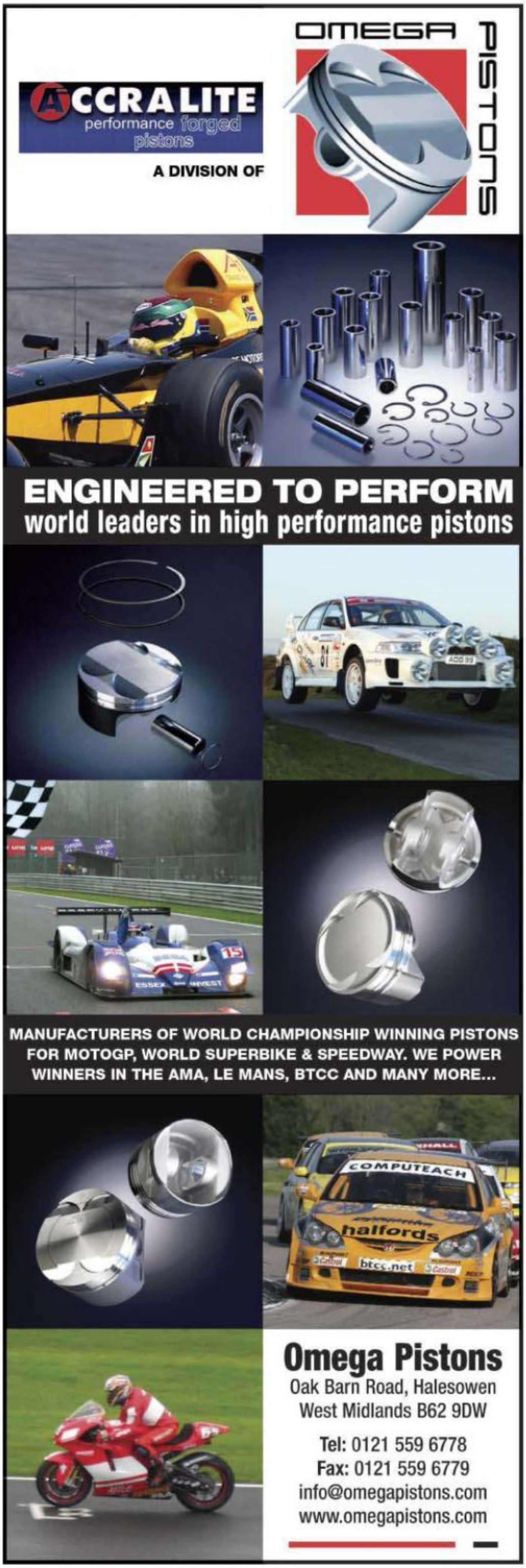


Figure 10

Using -L/D as a performance indicator would suggest an end plate depth of 400mm would be best in this case

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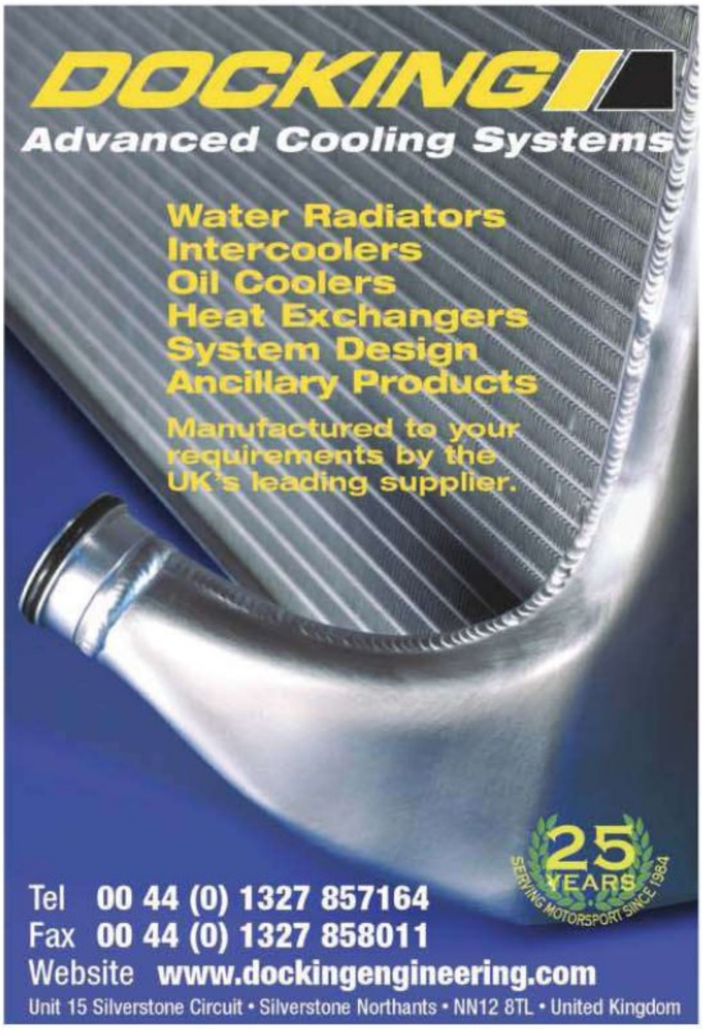
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Perfectly adequate

The latest incarnation of the Courage LC75 chassis is a competent all-round performer, yet the series it has been created for lacks the sparkle the car deserves

The ORECA LC75 is a high quality LMPC racecar, with an LMP1 chassis and components, but at a fraction of the cost

BY SAM COLLINS

The Courage LC75/LC70 chassis is one of the most prolific designs in modern endurance racing, and one of the most adaptable. In Le Mans Prototype (LMP) configuration it has worn four different manufacturer's badges - Courage, Acura, ORECA and HPD - and been fitted with seven different engines. In 2009, the latest incarnation of the LC75 was revealed by ORECA, the French engineering firm that bought Courage Competition in 2007. Designed for a one make feeder formula for the Le Mans Series, the FLM09 mates the GM LS3 V8 engine with the LC75 chassis.

'Our goal was to have a car with very high quality, reliability and a complete budget for the season, without any surprises,' Alain Marguet, the Formula Le Mans coordinator, revealed at Le Mans in 2009. 'We chose to use the Courage chassis, and it is exactly the same as the LMP1 design. After that, we chose a strong American engine, and we modified some parts for reliability, like fitting a dry sump and Marelli electronic injection. For the transmission, we chose a proven Xtrac gearbox, which we think is the best in the racing world, and fitted a Megaline shifter. It is one of the best systems and as used by Audi. That is a guarantee of reliability.'

Reliability was a key consideration for Marguet and the ORECA engineers, but they also focussed on cost control. 'With high quality components we guarantee that the teams will run the whole season without having to rebuild the engine or the gearbox, with the same brakes and discs all season.'

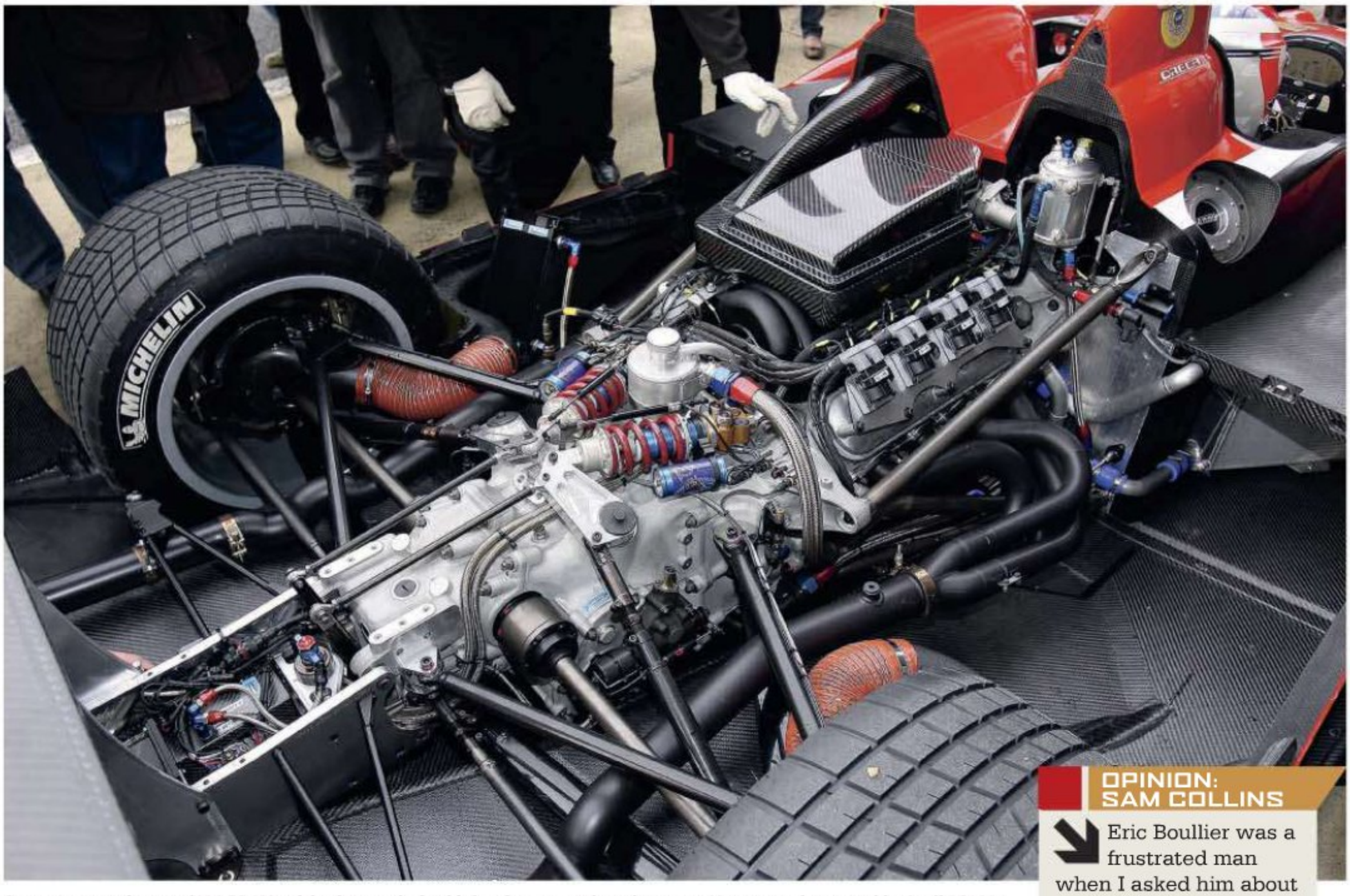
The FLM09 is fitted with Brembo carbon-ceramic brakes, not at first glance a low cost option, but Marguet explains: 'A lot of people don't know that although carbon is a little bit more expensive to buy, you have to change the steel equivalents every race. If you add it up throughout the entire series it is more expensive to use steel. The wear on carbon is so small we

> **“keep it cheap, keep it reliable' mentality”**

TECH SPEC

ORECA LC75

- **Class:** LMPC
- **Chassis:** carbon fibre and honeycomb monocoque
- **Weight:** approx 900kg
- **Engine:** 6200cc GM LS3
- **Power output:** 430bhp
- **Torque:** 630Nm
- **Lubrication:** dry sump
- **ECU:** Magneti Marelli
- **Suspension:** double steel wisbones with pushrods, rocker arms driving spring / damper units
- **Front tyres**: 30/65 – 18in
- **Rear tyres:** 31/71 – 18in
- **Gearbox:** Xtrac, six-speed sequential with steering wheel-mounted paddles
- **Brakes:** ventilated carbon discs, monobloc calipers
- **Safety equipment:** six-point harness adapted for Hans system, safety rubber fuel tank
- **Bodywork:** carbon / Kevlar light lamination



Power comes from a GM LS3 V8 with electronic fuel injection, mated to the same Xtrac gearbox used in Audi LPM1s

have the same disc for the entire season. That means you do not buy a disc, you buy the car. There is a set of discs on the car and you use it for a year.'

Marguet felt that many spec racing series did not offer good value for money and he was conscious that the FLM09 not be just another example of that. 'There are some other championships where the cost for a season is 1.5 million Euro ($2.04 million), it is crazy. They spend so much money because they go to such lengths to develop the cars. The engineers are happy, but the drivers do not race!

They spend the money on technical studies, yet the racing is meant to be for racing drivers not for engineers! If you look [around] today, the single-seater championships are blocked. All young drivers dream of becoming Formula 1 drivers but, if you look at how many new drivers appear in F1 each year, it is one or two, maybe. But if you look, all of the good career drivers are here, with Audi and Peugeot. For a driver wanting to make a career from racing, it is better to be in a Prototype than in a single seater.'

This 'keep it cheap, keep it reliable' mentality ran throughout the car's development. For example, the FLM09 teams running the car in the one-make series had only two choices of suspension spring, and only two sets of gear ratios for the whole season. 'We don't want to impose a new car on the teams each year just to make money. That is not our goal. So we chose an engine that, if we want to, we can improve very easily and in a cheap manner. This, however, has not been an issue so far,' continues Marguet.

Renault F1's team principal, Eric Boullier, ran FLM09s in 2009 when he was the technical director of Dams and was impressed. 'I think that it is a very good combination, with a good ratio of cost, technology, speed and performance. They are very fast and, on the small track at Le Mans (the Bugatti circuit), we have been not so far off the LMP2 cars. The car behaves like a proper Sportscar, with the same sort of downforce. I am pretty sure a driver who can handle this car can do well in LMP1.'

In 2010 the Formula Le Mans spec championship was amalgamated into the Le Mans Series and introduced into the ALMS as the LMPC class. To prepare it for this, the FLM09 received a minor update for endurance racing. The reliability and design of the cars was really put to the test though when the LMPC grid joined the ALMS at the Sebring 12 Hours - generally considered one of the world's toughest races. If the car's credentials weren't already obvious, the highest FLM09 finished in tenth position overall, beating two full-blown LMP1s in the process.

> **"a good ratio of cost, technology, speed and performance"**

OPINION: SAM COLLINS

Eric Boullier was a frustrated man when I asked him about the FLM09. He was impressed by its design and build quality, but said the car did not leave him much freedom to develop it. 'They are so limited for us, there is little for us to engineer,' he told me. The fans too find a class made up entirely of a single design fairly repulsive, complaining that the FLM09s are boring.

For my part, whilst I can see that the car is a superb piece of kit, I also find it frustrating. Why could we not have a proper LMP3 (or LMPC) category? Here is a way it could be done but still kept cheap: allow Lola, Pescarolo and Welter Racing to supply their LMP chassis to the series and allow teams to fit a fuel injected version of any Late Model engine. That would make it cheap, reliable and more exciting. But that won't happen and, if you want open engineering, you will still need an LMP2 budget. Shame.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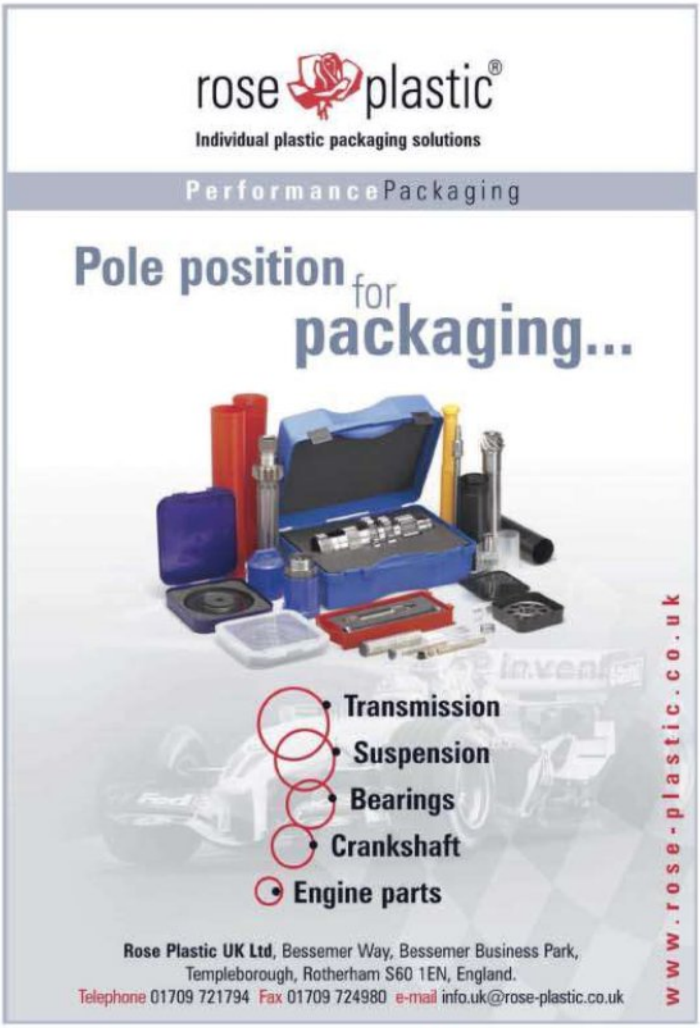
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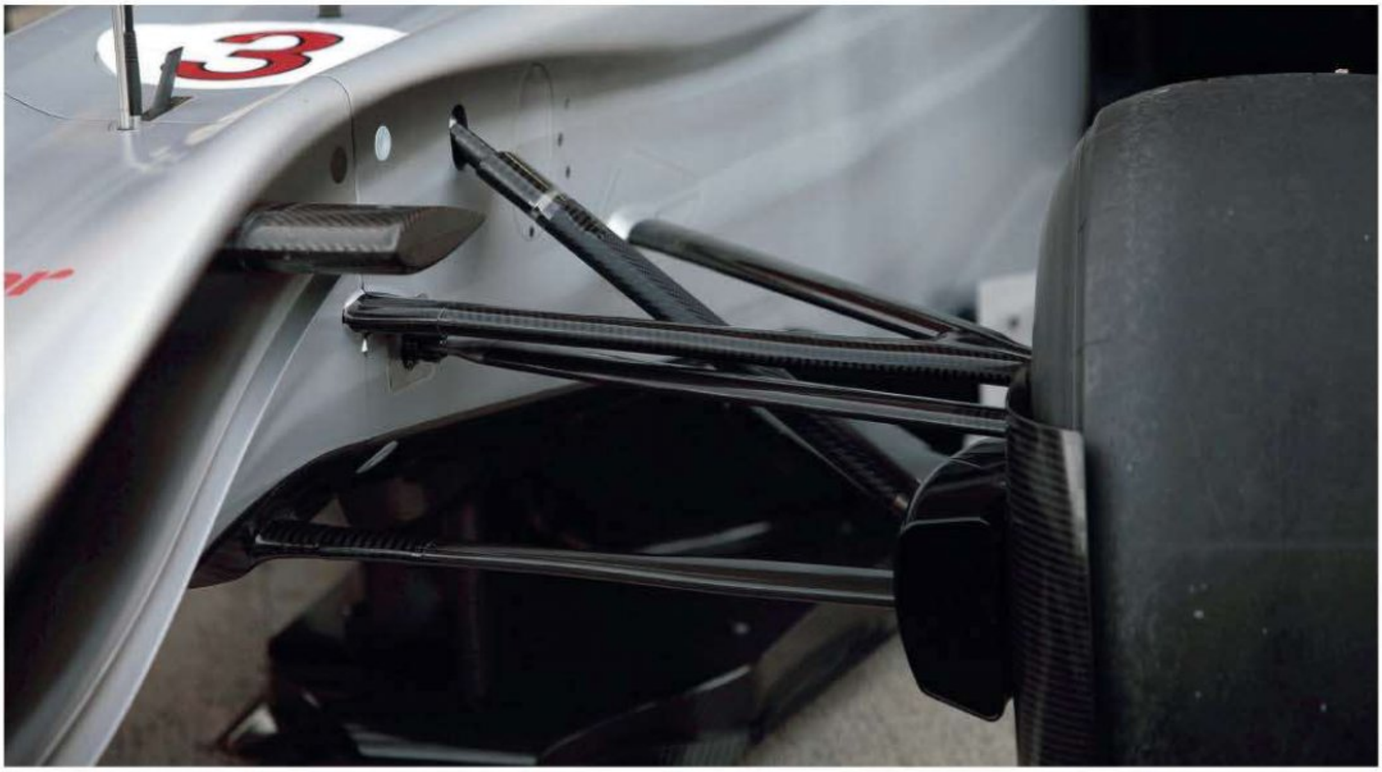
Behind n-lines


LAT

Furthering our understanding of the mechanics of acceleration using kinematics

BY ERIK ZAPLETAL

Last month we looked at the mechanics of acceleration from a static viewpoint, now we need to introduce some kinematics. In three-dimensional space any body, such as a wheel, has six degrees of freedom of motion relative to any other body, such as the car's body. The control arms of a suspension constrain five of these degrees of freedom, giving the suspension its 'kinematic' (sometimes referred to as 'geometric') properties. The sixth degree of freedom – a generally up and down motion – is controlled by the 'elastic' and 'viscous' properties of the spring and damper.

Fortunately, with the exception of the last few examples at the end of this article, we really don't need to know many details of the suspension's kinematics. Rather, we can do most of our work knowing only the path that each wheel print takes as it moves up and down against its spring / damper. Kinematically speaking, we only have to find the 'n-lines' for the centre of each wheel print as the suspension moves between its end stops. The n-lines are the lines that are normal to, or at right angles to, the path of the wheel print. Or we can think of them as lines along which no motion can occur.

> "In three-dimensional space, any body has six degrees of freedom of motion relative to any other body"

So how do we find these n-lines for a suspension that is still on the drawing board? The standard approach, taught in most suspension design textbooks, is to find the instant centres in end view and side view, then draw lines from these to the wheel print centre. These are the lateral and longitudinal n-lines, often called the control arm force lines.

Unfortunately, this method doesn't always give correct results. The problem is that instant centres are a two-dimensional concept, and the simplistic extrapolation to three dimensions (done by joining the two instant centres to give an instant axis), is simply wrong. The clue here is that after claiming that 'the instant axis defines the motion of the wheel spindle' most textbooks go on to look at different bump steers caused by different steering arm positions. If the same instant axis can have different bump steers, then it clearly doesn't have complete control of the wheel spindle. And, as we shall discuss soon, in side view the control of wheel rotation must also be considered.

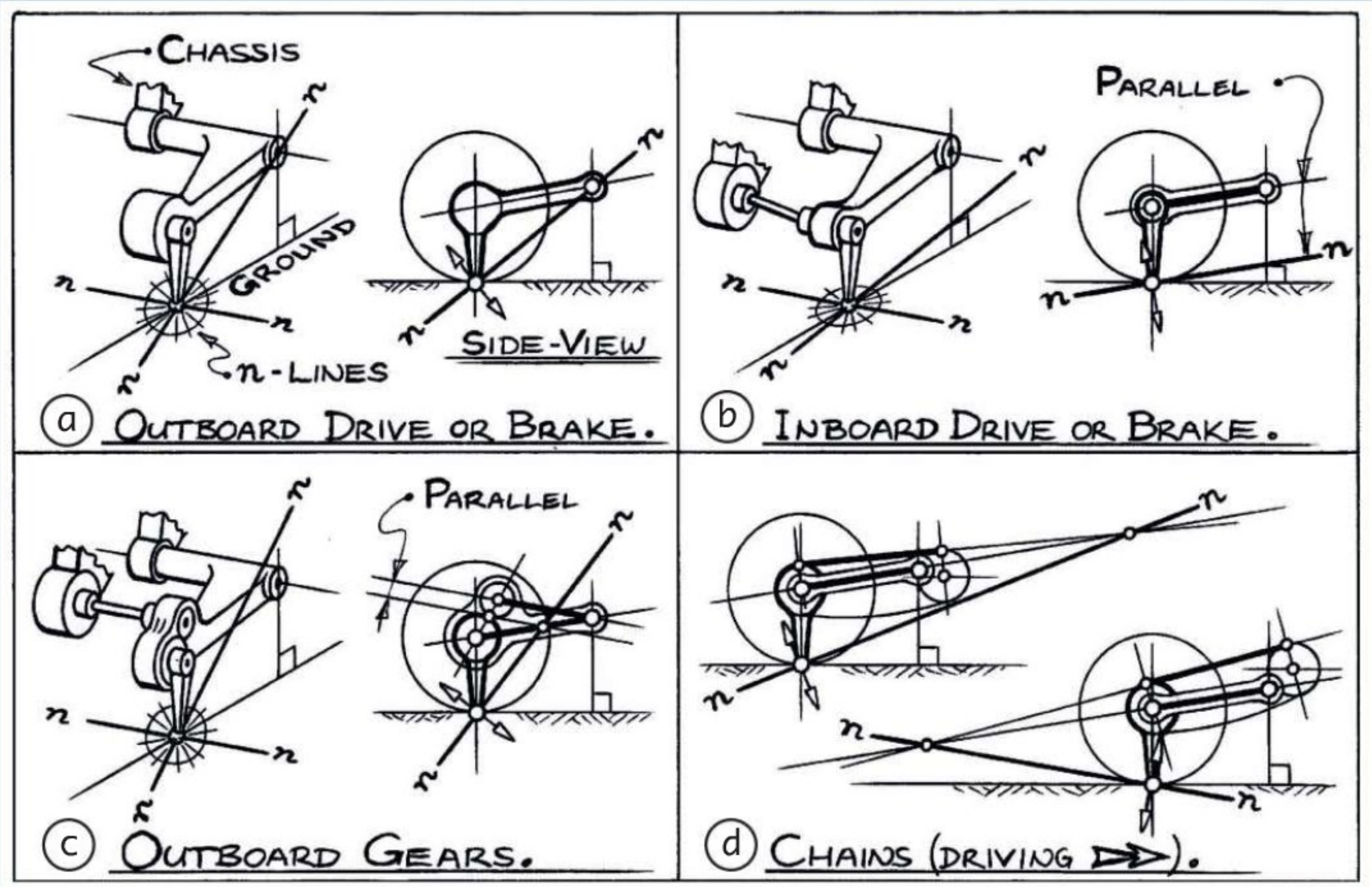
The correct way to find all the n-lines, on paper at least, is to find the 'motion screw' for relative motion of the wheel and car body. The motion screw, also known as the instantaneous screw axis (ISA), is the alpha of the kinematic alphabet. It is the most basic description of any motion whatsoever, between one body or reference frame and another. It is a simple concept, like a nut screwing onto a bolt. It was known in the middle 1700s, and its mathematics were thoroughly described by Irish mathematician Robert Ball in the late 1800s.

So, it is a sad indictment of the auto industry that this author has never seen it mentioned in any textbook, or paper, or computer program on vehicle dynamics or suspension design. However, we shall defer a full discussion of motion screws and suspension kinematics to another

SIMILAR SUSPENSIONS, DIFFERENT n-LINES

Figure 7

These diagrams show four similar trailing arm suspensions, but with different constraints to wheel rotation. The n-lines are all the same in end view, namely horizontal, but vary greatly in side view according to their rotational constraints



time. This is partly because if we consider beam axles, which usually have two degrees of freedom relative to the car body, then we also have to describe the 'cylindroid', an oddly twisted surface swept out by a single infinity of motion screws. But, fortunately for our investigation here, we don't need most of these kinematic details.

If we already have the suspension built, or we can build a model of it, even on paper or computer, then we can find each wheel print's path of motion, and hence the n-lines, by simple experiment. Practically, we support the car's body, remove the spring / dampers, replace the wheels with short legs going from axle down to wheel print, then trace the path of the foot of these legs as we move them up and down. We do this in end view and side view. Crucially, when doing this in side view we must somehow constrain the wheel leg from rotating. This is because this constraint is effectively a control arm for one of the aforementioned degrees of freedom.

The key to finding the correct n-lines is that whatever it is that produces the force that accelerates the car must also be that which constrains wheel print movement. There must be a path for the chain of forces between car body, wheel print and road. So when considering forward acceleration we lock the drivetrain, perhaps by clamping the inboard end of the driveshafts. When considering braking, we lock the brakes, perhaps with a wedge between caliper and disc. And so on.

> **the front and rear spring rates determine the centre of pitch motion**

We don't have space here to give a full justification of why we can expect correct results knowing so little about the suspension but, for those who have doubts, what we will say is that it goes back to the Greek mathematician Archimedes of the third century BC, and his proof of the Law of the Levers. Roughly speaking, if this method is wrong, then any competent blacksmith could build a perpetual motion machine that not only runs forever, but also produces unlimited energy. This hasn't happened yet, so the method seems reasonable. For a more complete explanation, the reader can look up the Principle of Virtual Work.

BASELINE - THE MODERN WAY

We will now consider in some detail a baseline case of an accelerating car that has horizontal n-lines, and consequently no anti properties.

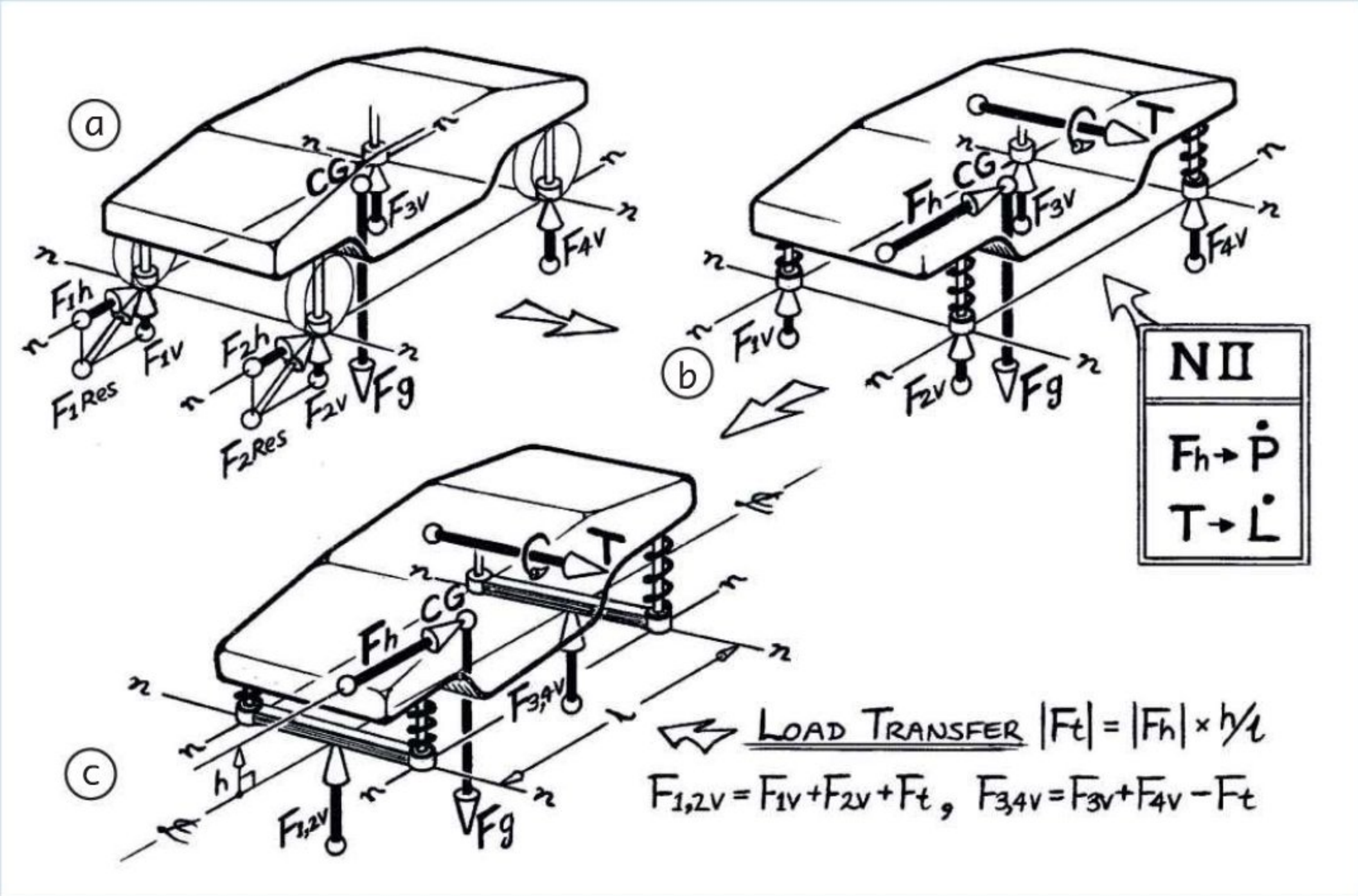
While a forward accelerating car is the default in most of the figures from now on, the reader might also see the pictures as representing a car moving to the left and braking with its front wheels only. Or it might be a car moving to the top left of page, turning right and generating a cornering force with its left wheels only. The mechanics are essentially the same in each case.

It is worth noting here that the pitch motion of the car, and even its c of g height (h) depend strongly on the spring rates. Obviously, the stiffer the springs the less they compress or extend for a given load transfer (Ft), and the less the pitch angle change of the car. Conversely, the softer the springs the more the pitch

ACCELERATION WITH HORIZONTAL n-LINES

Figure 8

These diagrams show the approach most commonly used today. Here we are looking at a rear-drive car as it accelerates forward, to the top right of the page. To simplify things, assume the car is symmetric, left to right. For now we neglect the mass of the wheel assemblies and shrink them down to simple sliders at the wheel print positions



(a) Figure 8a

The car is stationary. Gravity acts between every particle of the car's body and the Earth, producing a large number of small forces pulling down on the car. We add all these small forces together to get the resultant force, Fg. Fg acts through a point in the car's body known as the centre of gravity (c of g), sometimes also called the centre of mass. Gravity is a distributed force, so it doesn't actually act at the c of g, but for a rigid body we can always find *a* point through which the resultant of all the mass-based forces pass.

The gravitational force, Fg, is brought to equilibrium by the great many individual forces of the road particles pushing up against the tyre particles. Again, we add these many small forces and draw the resultants passing through each wheel print centre as F1v to F4v. This addition process invariably results in a couple accompanying the linear force at each wheel, but since these are small we can ignore them here.

At some time the rear wheels start to push rearward against the road, and the road reacts forward with horizontal forces F1h and F2h. Once again we stress that there are many individual road-to-tyre-particle forces involved, with many different directions. But to simplify the picture we draw only the resultant force, Fres, or a small number of components of the resultant

(b) Figure 8b

We sum the two horizontal road-to-wheel forces F1h and F2h. We then transfer the resultant Fh up to the point CG and add the couple T to compensate for the move, as in figure 3. The magnitude of this couple is given by |T|=|Fh|.h, with h being the c of g height. The consequences of the force Fh and couple T acting on the car are shown to the right of figure 8.

For the force Fh this is Newton's Second Law of Motion, which states that Fh changes the 'quantity of motion' of the car, with this change in the direction of Fh. In modern terms, Fh changes the 'momentum vector P' of the car. Or, put more simply, the car accelerates forward. Similarly, the rotational version of Newton's Second Law states that the couple T accelerates the car in a nose-up / tail-down pitching motion. The linear acceleration of the car continues until some other force, such as aero drag, brings Fh to equilibrium. The rotational acceleration stops much sooner as the changing vertical components of the road-to-wheel forces, F1v to F4v, bring T to equilibrium, possibly after some oscillation

(c) Figure 8c

The situation with couple T brought to equilibrium by the new vertical components F1,2v and F3,4v - these being the forces for each axle. Using the algebraic approach we calculate that F1,2v has increased, and F3,4v decreased, both by an amount known as the load transfer (Ft), such that |Ft|=|T|/l, with l being the wheelbase. Since |T|=|Fh|.h, we have load transfer |Ft|=|Fh|.h/l. So the load transfer from front to rear wheels depends only on the magnitude of the accelerative force Fh, the height of the c of g h, and the length of the wheelbase l. At equilibrium, this is always the case, regardless of suspension design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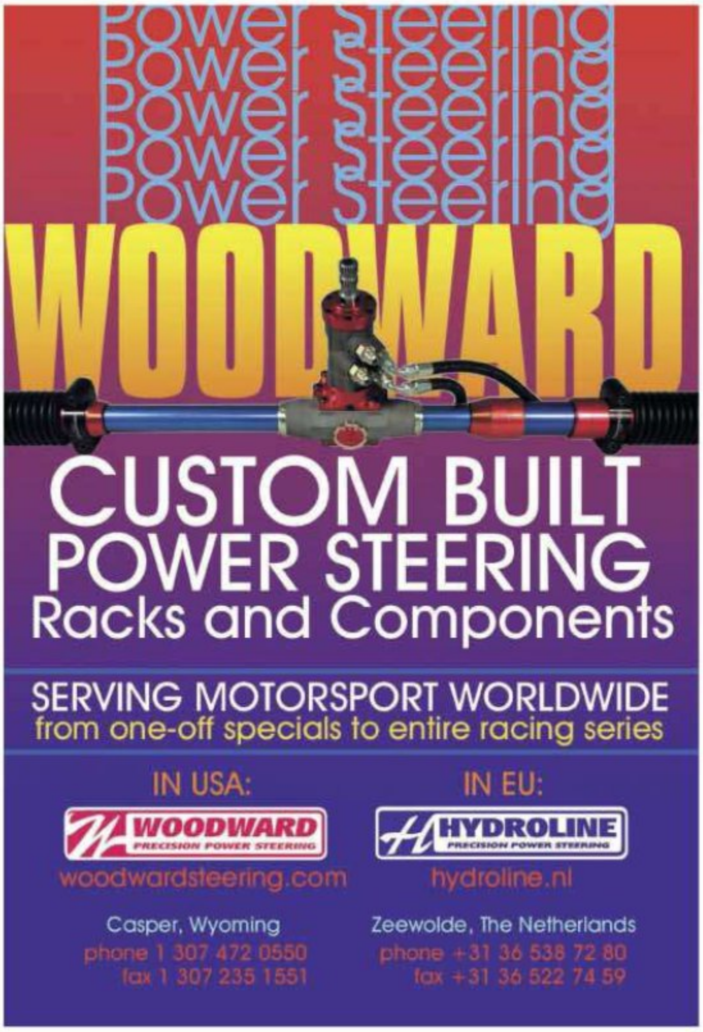
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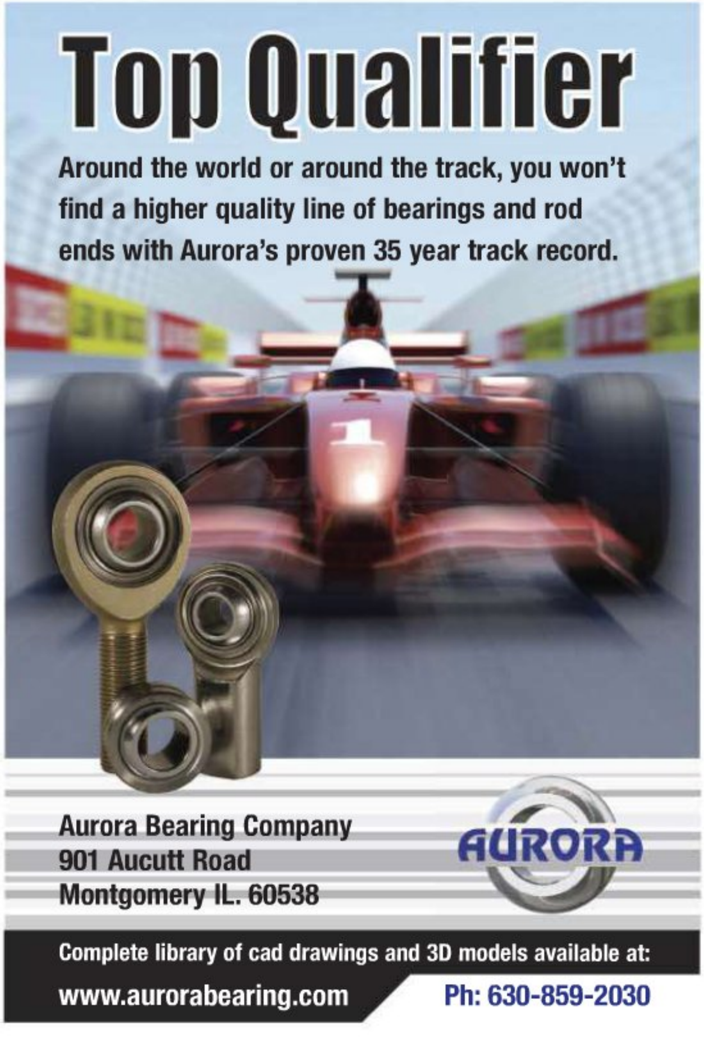
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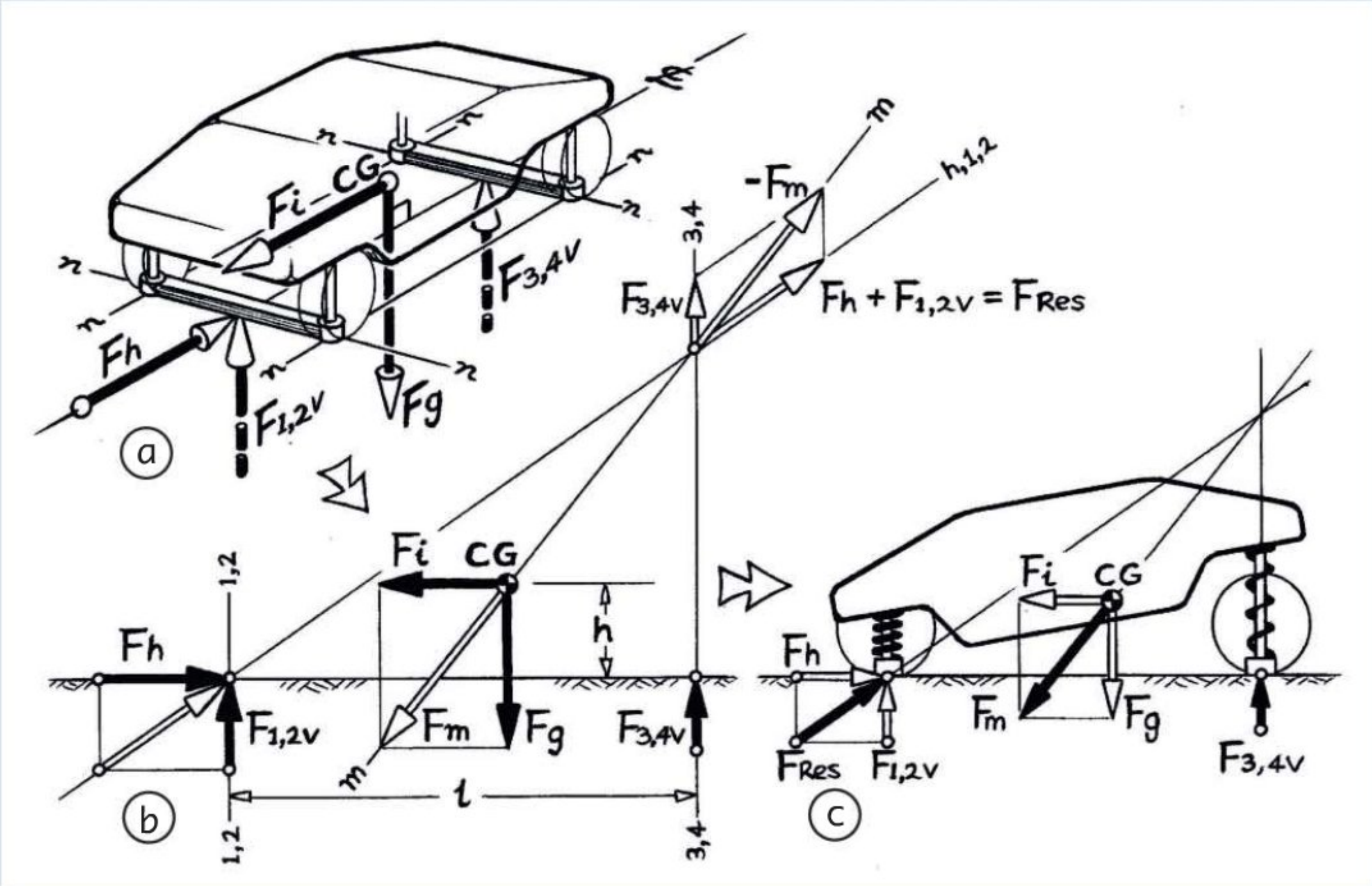
D'ALEMBERT'S PRINCIPLE

Figure 9

Considering the baseline case using the older geometric method of analysis



a Figure 9a
With a picture of the car and the resultant gravitational force (Fg) drawn to some appropriate scale. We draw the horizontal driving force (Fh) to the same scale. So if we want the car accelerating at, say, 0.8*g*, then Fh is 0.8 times as long as Fg. Also pencilled in are the vertical components of the road-to-wheel forces, although the magnitudes of these forces are as yet unknown.

Note that Fg is drawn pulling on the c of g, while the road-to-wheel forces are pushing on the wheels. This pull or push is arbitrary since the sliding nature of forces means we can draw them anywhere along their lines of action. Also, we are still using perspective drawing to give the reader some feel for the problem. Ordinarily, we would use two-dimensional drawings

b Figure 9b
Here we use a graphic method to calculate the magnitudes of forces F1,2v and F3,4v. This is a standard statics technique, used for truss calculations and the like. We start with Fg, Fi, and Fh as the knowns and, as such, also know the resultant of Fg and Fi, namely Fm, with m for mass-based force. And we know that when we add Fh to the two unknowns F1,2v and F3,4v, their resultant must bring Fm to equilibrium. It therefore must lie on Fm's line of action, namely m-m. So we draw a vector -Fm at the intersection of Fm's and F3,4v's lines of action. From this point we draw a line down to the intersection of Fh's and F1,2v's lines of action, on which their resultant must lie. Lastly, we apply the parallelogram rule where needed and the magnitudes of F1,2v and F3,4v fall out

c Figure 9c
This simply shows the likely motion of the car's body when subject to the depicted forces. The forces squashing the rear springs and control arms are obvious. The front-to-rear load distribution is also obvious, being indicated by the intersection of Fm's line of action and the ground plane. The comments regarding the influence of spring rates on the car's pitch and heave motions apply equally here as in figure 8

angle changes. Less obvious is the fact that the front and rear spring rates determine the centre of pitch motion. If this centre doesn't coincide with the c of g, then c of g height h will change with pitch motion. For example, with equal spring rates the car pitches about the mid-wheelbase position. So the c of g rises if it is closer to the front wheels, and falls if closer to the rear. But with a mid-wheelbase c of g, and stiff rear springs and soft fronts, the c of g rises. And with stiff fronts and soft rears, the c of g falls.

Spring rates become very stiff when they reach their bump and droop stops. So a car that has droop limited front springs has a very stiff front spring rate for extension, but a possibly much softer rate for compression. This may result in the c of g falling during both acceleration and braking. Likewise, the nose, and possibly also the c of g, is likely to fall during cornering.

So even though this baseline car has horizontal n-lines, no antis, and therefore no 'jacking' forces, the c of g height is very likely to change during horizontal accelerations. Changing c of g height, or heave motion, directly affects load transfer, with more height giving more load transfer. Since the load on the tyres directly affects their grip, any heaving motion directly affects the car's grip and balance. Heave motion can also affect aerodynamic performance, especially that due to the underbody.

If pitch motion occurs about the c of g, then it doesn't change load transfer, but it can affect aero. So, of the two, heave can be more deleterious to performance than pitch, and should be the one more closely watched. We note that from the driver's seat pitch and roll angle changes are relatively easy to detect, with the position and angle of the horizon changing relative to the car's bodywork. However, heave changes, even quite large ones, are almost impossible to detect.

USING D'ALEMBERT

We now consider the same baseline case as in figure 8, but this time using the older geometric method of analysis. We start in figure 9a.

> **"heave can be more deleterious to performance than pitch"**

Our next step, and the only controversial aspect of this method, is that we draw the resultant 'inertial reaction force' (Fi) acting through the c of g, and with equal magnitude but opposite direction to Fh. This force Fi is a distributed mass-based force and the earlier comments about gravity apply equally to Fi. This step is known as the use of d'Alembert's Principle, after the French mathematician and philosopher Jean Le Rond d'Alembert of the middle 1700s. It is a way of turning a perhaps difficult problem in dynamics into a simpler problem in statics.

The inertial force (Fi) is what we feel pressing us back into our seats when accelerating down a drag strip. Acting in the opposite direction, it throws us forward during braking. And the centrifugal, or centre-fleeing, force that throws us sideways during cornering is similar. These forces arise whenever a massive body accelerates relative to inertial, or non-accelerating, space. The problem here is that in the modern teaching of science these forces are considered *not* to be forces. They are considered unreal and often called fictitious forces. In some circles it seems almost a hanging offence just to mention these, er, phenomena.

This is unfortunate for many reasons, of which we mention only three here. Firstly, this viewpoint is based on a philosophical argument that in the author's opinion is flawed. No one has ever proved that inertial forces are any less real than, say, gravitational forces, which themselves are poorly understood. At the moment it is really only a matter of arbitrary definition, with gravitational phenomena being defined as real forces, while inertial phenomena are defined as figments of our imagination.

Secondly, use of d'Alembert's Principle, as in figure 9, always gives exactly the same results as the currently approved method of figure 8, provided both are carried out correctly of course.

Thirdly, and most relevantly to our problem here, d'Alembert's Principle seems to make the problem easier to understand. For example, in none of the drawings of figure 8 is it obvious how the rear suspension is squashed between the road-to-rear-wheel force and some sort of reaction at the car's body. In each drawing there is only one horizontal force (Fh) shown. There is the couple T shown in figures 8b and 8c, but now the driving force Fh has disappeared from the rear wheels. Does this mean that the rear control arms have no force acting though them? You decide. For many people these pictures don't evoke the same kinaesthetic sense as those shown in figure 9.

Next month, we will continue this investigation and look more closely at how all this relates to anti-dive and anti-squat...

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The future of CFD?

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There's a quiet revolution going on in the world of CFD, as free 'open source' software challenges vendor-supplied products. Could this be the way forward for race teams?

BY SIMON MCBEATH

Since computational fluid dynamics (CFD) software became generally available there has really only been one legitimate way in which an organisation could get hold of it: pay a vendor either a one-off or, more likely, an annual license fee. The fees are generally thousands of pounds/dollars/euros per processor per annum. But then along came 'open source' CFD software, which enabled the latest release to be downloaded free of charge at any time. Immediately, a number of obvious questions sprang to mind. Fundamentally, was it really free? Was the software as good as the commercial codes? What was the catch? Was its presence going to be sustainable? And what would happen to the 'traditional' vendors' market share now they were competing with a seemingly free alternative? It is believed that at least one Formula 1 team is using open source CFD to meet its needs, so *Racecar Engineering* decided to investigate where we are with open source CFD software, and ask the very questions of its developers, its users and the major CFD vendors that we were previously asking ourselves.

First, what are we referring to under the blanket term 'open source' CFD? Well, the name on most people's lips is OpenFOAM, supplied by OpenCFD Ltd, a UK-based organisation that has built its business around supplying free CFD software (see sidebar on p62). But the range of open source products includes meshing and post-processing software, as well as the solver code, and some of these come bundled with OpenFOAM, while others are downloadable from other open source, er, sources.

SO WHAT'S THE DEAL?

Unsurprisingly, using open source CFD software follows the same process as vendor-supplied software, but what is radically different is the underlying business model. Dr Rob Lewis, whose company TotalSim Ltd is a leading independent CFD service provider and an enthusiastic user of OpenFOAM and other open source resources, explained the differences: 'With a commercial vendor you pay for a disk and a license key. What you get, sort of for free, is support and training and so on. What you get with OpenFOAM is free software and what you pay for is support, training and any developments you request. So you pay for what you want.

'The commercial vendors are now seeing this as a real threat to their business. But they charge for extra licenses because you've got four processor cores and not two... We've got 700 cores and 15 people. If we were paying a commercial fee for licenses we couldn't have 700 cores and 15 people and still make a profit. It's as simple as that. You can get good deals from CFD companies, but you've got to be careful that the good deal scales if necessary, and that it doesn't run out in a year, and so on. To build a business around CFD you've got to have those securities...'

THE USER COMMUNITY

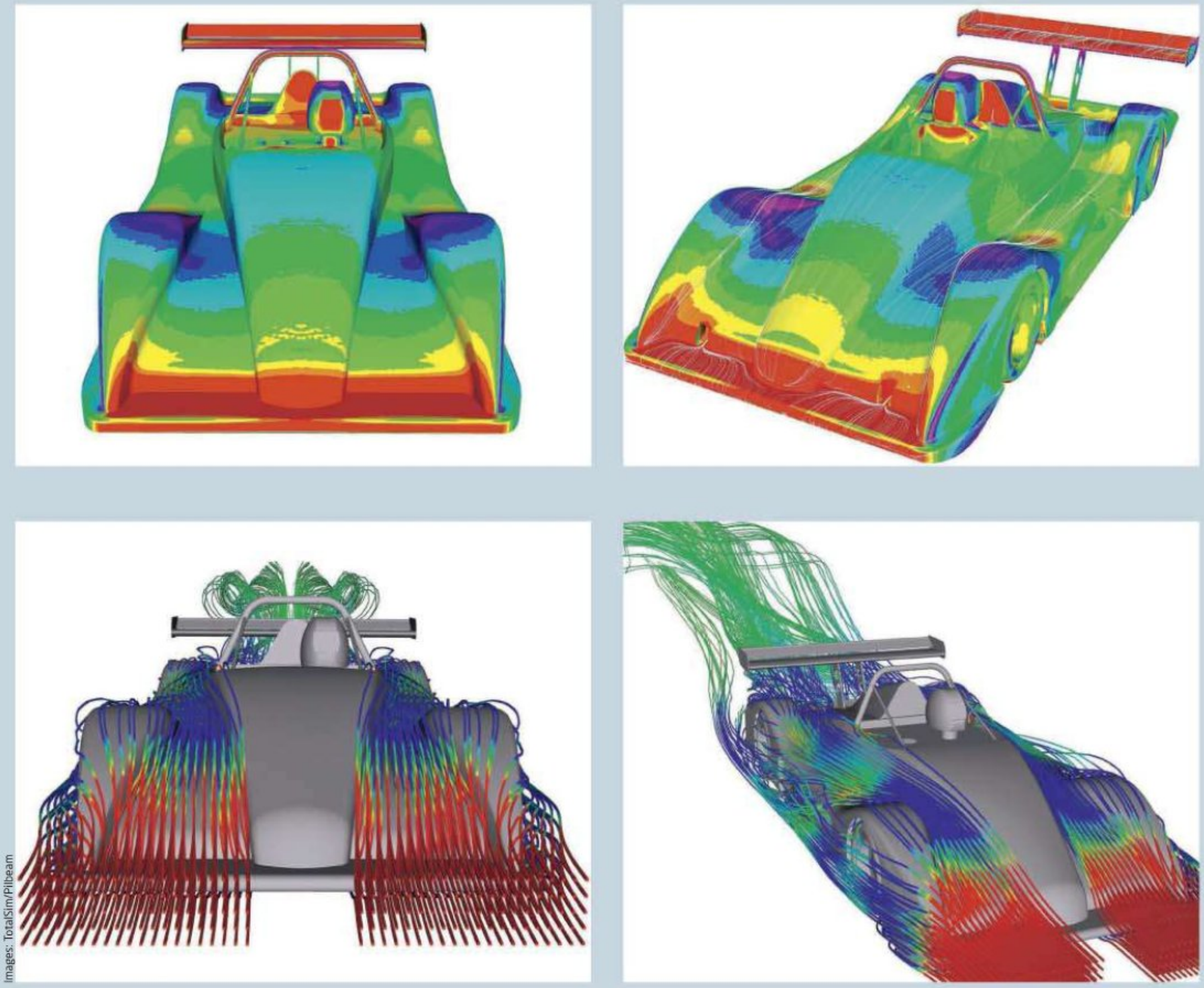
Avoiding a sizeable fee per processor is the major driver behind the accelerating uptake of OpenFOAM at the moment. The suite of tools is freely available, and being 'open source' means that they are open to development by the so-called 'user community'. And for those able to fully utilise the tools they can be implemented on large parallel processing computer networks without the financial pain incurred by the usual license arrangements. Instead, the money 'saved' by using free software can be invested – for example, into relatively low cost hardware to develop the kind of computer clusters that TotalSim has built for itself, and also in developments of the software for your types of application.

> **"Avoiding a sizeable fee per processor is the major driver"**

So the software might be free, but there are costs involved. However, the heavy hitters, recognising the longer-term benefits of avoiding annual fees, are willing to invest in paying specialists, including OpenCFD itself, to develop the basic OpenFOAM tools into what they need to get the job done. But this is where the open source principle challenges the conventional business mind, because developments, enhancements and add-ons to the code should in theory be made freely available to the user community at large. The cynical bystander would be forgiven for thinking that companies spending substantial sums on developments are unlikely to want to then give them away, at least not without giving themselves a decent head start. Lewis of TotalSim again: 'It requires a really different way of thinking. You're not paying a license fee, but you have to share. We must all provide feedback, and it's for everybody's benefit. To go with open source, you've got to go with an open mindset. It takes a little while to get your head around that, and it's probably a bit socialist but it works!'

Another downside to not contributing to the community was further explained by Lewis: 'You could take the source code and grow your own whistles around it that you don't release to the community.

OPEN SOURCE VISUALISATIONS



Images: TotalSim/Pilbeam

But when OpenFOAM's next release appears you'd have to re-integrate your whistles into the main code again, which can be a massive effort. If you don't release back you pay the pain, as well as going against the whole ethos.' So it's not about altruistic contributions for the betterment of OpenFOAM, it's simply a different kind of business model.

HOW GOOD IS IT?

Another organisation soon to commit to OpenFOAM is UK-based MIRA, and chief aerodynamicist Dr Angus Lock is already using some open source CFD tools, including snappyHexMesh from OpenCFD, which, he says, 'works really well'. He has also successfully used the OpenFOAM solver for steady state external aerodynamics, but has yet to run thermal or transient aerodynamic cases. MIRA also uses ParaView, an open source post-processing package for data analysis and visualisation. According to Lock, 'it knocks commercial post-processing applications for six' (the cricketing equivalent of a home run!). TotalSim also uses snappyHexMesh and Paraview.

'The big plus of open source,' continued Lock, 'is the ability to interact with the source code. This can take years with the commercial vendors, but with open source, first of all you can consult the online forums and user groups, which might provide solutions to problems or needs, but also the developers are very responsive. With open source you can spend just a proportion of licensing costs and really influence the code. You can contribute to the community and MIRA is keen to push any bits it develops out there pretty quickly.'

It seems unlikely that this enthusiasm would exist if the basic software were no good, even with the financial benefits. As is now generally known, some of the major automotive manufacturers have invested heavily in OpenFOAM, and one has apparently benchmarked it against one of the most technically respected commercial codes. The conclusion seemingly was that the commercial code offered no particular advantage.

So, with all this in mind, why isn't everyone using OpenFOAM? An analogous case is that of Open Office, also open source, free, and apparently universally compatible with and, according to many, better than Microsoft Office. So why does Microsoft continue to dominate that market sector? Possibly because people think that open source means 'no technical support'. Indeed, the perception may be even more vague than this, and is simply a reluctance to go with anything that's free because 'it can't be as good as something you pay for.' But the experiences outlined here, and the fact that major automotive organisations and Formula 1 teams are using open source CFD suggests these concerns are groundless.

Another possible obstacle is that OpenFOAM runs under the (open source) Linux operating system, with no

Provisions
Open source CFD provides a range of visualisations, including surface pressures, surface oil flows and streamlines, as seen on the Pilbeam (shown left)

THE VENDORS' VIEWS

Racecar Engineering contacted a number of the major CFD vendors who collectively supply much of the motorsport CFD market to ask for their views on free, open source CFD software. One 'declined to comment on the products of other commercial companies', another agreed to comment but then didn't. Two, however, did offer some observations. CD-adapco, suppliers of Star CD and Star CCM+ said, 'CD-adapco products are now only licensed on a per processor basis for a small number of processors (typically less than eight cores). Above that we offer a 'Power Session' license that allows our users an unlimited number of processors for a single annual license fee. This is particularly useful for Formula 1 teams that typically run simulations comprising hundreds of millions of cells, using hundreds, if not thousands of processors. The license fee allows access to a support team of specialist engineers, many of whom are dedicated to motorsport and vehicle aerodynamic simulation, and all of whom are connected to the code development team.' That doesn't sound too bad if you're a Formula 1 team then, though there is still an annual fee, even if it's cheaper than it was a year or so ago before this new pricing structure was introduced.

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> **PROF BRIAN SPALDING CHAM LTD**

The other respondent was the man who founded CHAM Ltd, and who is regarded as the founder of CFD itself, Professor Brian Spalding: 'From its inception, a large part of the coding of PHOENICS [CHAM's CFD code] has been open to inspection and change by sufficiently knowledgeable users. Recently, OpenFOAM has been launched, of which the whole of the source code is open. What effect its existence will have on the CFD-code industry is not yet clear, but it may not be so profound as those who hope to see a reduction in licence fees for commercial codes such as PHOENICS expect.

'Racecar engineers who want to use CFD to improve their designs can certainly visit the OpenFOAM website and, in principle, find all that they need free of charge. All, that is, except the assistance that they will require in order to make use of what has been made available to them. Free-of-charge assistance is harder to find.'

However, as we have seen, the provision of this assistance, while not free, is readily available from OpenCFD and others, and indeed forms part of the business of those companies. In short, you pay your money and you make your choice…

OpenCFD Ltd

OpenFOAM was the brainchild of Henry Weller, and the product's beginnings go back to 1989 when he first encountered the C++ programming language. 'It struck me immediately that this was a better language to write a complex physics code. So I started playing around with ideas and, by 1999, it was a pretty capable, wide-ranging CFD code. I created [a company called] Nabla and marketed [the code as] FOAM. That was successful in that the company was profitable. But after four years I decided this wasn't the right way to go. With the way FOAM was structured, and with the kind of users and usages we had, what we wanted to achieve was going to be easier to do in open source. So we took a gamble and, in 2004, I set up OpenCFD.

'It made it much clearer to market the product to get development work because instead of clients saying "we'll use it when you do the development", we turned around and said, "we'll give you the code and everything for nothing but, if you want anything new, you have to pay for it." And everybody went, "whoah, that's weird!" It took time for that to sink in but, after a while, they said, "no, actually that's fair, we only pay for what we want. The only thing is, if *we* pay for it, why should we let *you* give it away?" So we said, 'we've given away everything that we've ever done over 20 years, everybody else is going to give things away. It's now a club basically, so do you want to join or not?' Some companies got it immediately, and some got it… eventually.

'I think Rob Lewis [now at TotalSim] was keen on OpenFOAM but it was quite a weird move for Advantage CFD [the original organisation Lewis set up]. But when they got it, they really got it. And they paid us to do a substantial amount of important developments they were going to need for motorsport. That then got distributed, so their competitors could then use those developments. I don't think it's detrimental to their efforts because they could buy a commercial code and buying that doesn't stop competitors from buying it, too. And in paying for a license they'd be paying for developments that other people could use. So there isn't really a difference.'

> **"The aims of OpenCFD are to be there to help people who want to use it and are benefiting from it"**

What are Henry Weller's ambitions for OpenFOAM? 'The aims of OpenCFD are to be there to help people who want to use it and are benefiting from it. If that user base grows then we would want to grow as necessary to support them.

'Another thing is that some commercial products are quite unreasonably priced, but I think at least some are becoming more reasonable as a response to us offering a free alternative.'

To the individual or small team wanting to get into OpenFOAM Weller has this to say: 'I think somebody with the right 'computer attitude' could probably do it alone. With our training courses or the packages TotalSim offers, you could get up and running and it would cost you about the same in the first year as the license fee for a commercial product. But then you wouldn't have to pay anything more, that's the point.'

Contact: www.opencfd.co.uk

current distributions available for Windows or Mac OSX. Furthermore, there is no graphical user interface (GUI) supplied with it. While these are scarcely going to deter CFD professionals, the lack of a friendly GUI could be an obstacle to be overcome for smaller teams or CFD 'dabblers', although in reality Linux presents no real difficulties.

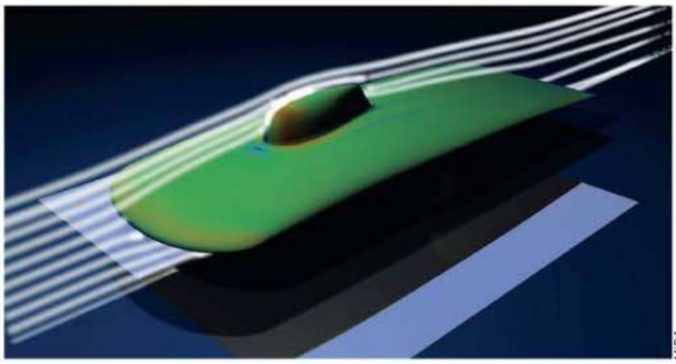
WILL THE CONCEPT SURVIVE?

It would seem then that OpenFOAM's long-term survival depends on users not taking unfair advantage of what's offered. But is this naïve? OpenCFD admits that some users have already violated its rights. What safeguards are there, other than the time and cost involved, preventing someone else producing a functionally similar but sufficiently different product and offering it as their own? OpenCFD's Henry Weller explains: 'We hold the copyright, and if we find violations of the GPL (General Public License) then we act. There are organisations that are building on GUIs and selling them. Okay, so formally they're selling the GUI but, in reality, they're selling usability of OpenFOAM, so they are seriously benefiting from the fact that OpenFOAM is open source. And the only thing you can do is accept there really is a market for that kind of feature, so we either want to encourage people to do an open source equivalent or plan for something ourselves. And if we can find enough interested people we should be able to find sponsorship so that we can do everything open source. We believe in open source.'

So what does the future hold? The confident view of those committed to open source is that traditional CFD companies will struggle to compete on the same basis they have been operating. Indeed, it would appear that the vendors have a choice to either ensure their products offer superior or unique capabilities or adapt their business through changes to pricing or service provision. Given the aforementioned preference of conservative users to remain with traditional purchased software, a market will likely remain. And the more reactive vendors are already 'adjusting' to retain market share. Meanwhile, a contrasting, if cynical, view on a possible future for open source software is that, as demand increases, it may not continue to be supplied free of charge. The law of supply and demand has deep roots, so time alone will tell.

In the meantime, one 'independent observer' gazed into his crystal ball and added these tantalising thoughts: 'I would suggest that the automotive aero section of OpenFOAM will soon be sufficiently capable for most users to achieve what is, and what could remain for the next two to three years, cutting-edge capability. By that I mean the ability to successfully run detached eddy simulations (DES) on entire car models without months of preparation or millions in license fees. The only requirement will be sufficient computing power, but that's getting cheaper every day. A just about worthwhile DES case of 20 million cells could be done by a home user with one really potent PC or a few cheap ones networked together. All it would cost is the price of the hardware.'

If this does indeed come to pass, then a great deal may change in the near future.



MIRA

The aerodynamic experts at MIRA have analysed Cambridge University's Eco Racing (CUER) solar challenger with OpenFOAM

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Photos: Wouter Melissen

Generation TX

The Howmet TX was not unique in being a gas turbine-engined racecar, but it was unique in being a successful one

BY WOUTER MELISSEN

While the gas turbine engine had almost completely replaced the piston engine in airplanes by the 1960s, the jury was still out on the turbine's usefulness in cars. Manufacturers like Chrysler and Rover experimented with turbines in road and racecars but, ultimately, dismissed the idea. Turbines nevertheless popped up again in the second half of the 1960s, when various racecars tried the engines once again. The most advanced and successful of this new breed of racers was the Howmet TX, which raced at Daytona, Sebring, Brands Hatch and Le Mans in '68.

The Howmet was the brainchild of American racer and engineer Ray Heppenstall, who managed to develop and build the first car in just five months. This was short by conventional standards but for a car this sophisticated seems virtually impossible. Heppenstall achieved the remarkable feat by using a surprisingly large number of existing parts, instead of engineering everything from scratch. The secret to the car's performance lay in the type of turbine engine he used, which was quite unlike any of the other turbines in the other (race) cars.

Born in Philadelphia, Heppenstall had been racing a wide variety of machines since the mid-1950s. He prepared his own cars and quite often modified them extensively. Among his many friends was Tom Fleming. The two men not only shared a passion for racing but also regularly shared a drive in the early 1960s. Fleming was also the vice president of the Howmet Corporation, which specialised in the production of precision aluminium components. Prior to the TX project, in 1967 Howmet backed one of Heppenstall's other projects – a Ford Falcon Sprint, which he extensively modified. The end result was a considerably lighter and more powerful Ford Falcon that was entered in the Daytona 24 Hours by Howmet and at the Sebring 12 Hours as the Howmet Falcon Sprint. The old car performed very well and, much to the dismay of the Ford GT40 drivers, proved very difficult to pass on the straights. Encouraged by the performance of the modified Falcon, Fleming discussed the possibility of building a bespoke, turbine-engined Howmet for the 1968 season. From a commercial angle, this made perfect sense, as the unusual engine would certainly generate a great deal of publicity for Howmet and its products, many of which were used in the construction of turbines.

CHOOSE YOUR WEAPON

Heppenstall's first order of business was to find a suitable turbine. He first visited General Motors' subsidiary Allison, where he was given a brief peak at drawings for an all new turbine engine designed specifically for use in a proposed Pontiac model. However, perhaps due to the company's ties with General Motors, Allison refused to supply Heppenstall with the engine. He had seen enough of the design though to describe to rival company Continental what he needed. As luck would have it, Continental had 10 turbine engines lying around, left over from an unsuccessful bid on a government contract for a military helicopter. These could easily be modified to suit Heppenstall's needs, so the company agreed to help him out.

One of the main problems with conventional turbines was the enormous response time or lag of the engine. In the most common turbines a compressor mounted at the front of the turbine would compress air into the combustion chamber. Here the fuel / air mixture is ignited, providing gas for the power-generating turbine at the rear of the engine. The compressor and turbine were usually connected by a shaft to help increase momentum. As a result, inputs to the engine would also suffer from considerable delay or lag. Heppenstall believed the lag could be as much as three seconds, both on acceleration and coming off the throttle.

> **"One of the main problems with conventional turbines was the enormous response time"**

Imagine having to come off the throttle three seconds ahead of the braking zone for a corner! The only place where this was not seen to be a problem, however, was on oval tracks – a point well proven by Joe Leonard, who placed his turbine-engined Lotus on pole at Indy in 1968.

Allison's ingenious solution for this problem consisted of using two sets of turbine blades. The first, gas-generating turbine fed the second one, which was connected to the output shaft. Controlling the amount of gas flowing from the first to the second turbine were two wastegates, controlled by the throttle pedal. The first third of the pedal's depression modulated the amount of fuel fed to the combustion chamber, while the remaining travel controlled the flow of compressed air through the wastegates. At 'idle' all of the compressed air was sent out of a single, central exhaust, but as the pedal was pushed to the floor the wastegates closed, feeding all of the compressed air to the power-generating turbine. Using this wastegate system, the gas turbine finally had enough characteristics of the internal combustion engine to make it suitable for use in a car. The only characteristic it lacked was

At idle, all of the compressed air is fired out of the central exhaust then...

...as the throttle pedal is depressed further, air is fed to the second turbine

Body was made from a combination of glass fibre and aluminium, the aluminium parts left bare to showcase the products manufactured by Howmet Corp

the retardation provided by a conventional engine on the over run. This necessitated additional emphasis being placed on the brakes of the Howmet.

As per Heppenstall's instructions, Continental modified the first of its engines during the autumn of 1967. Weighing in at a mere 77kg (169.8lb), the wastegate-equipped turbine engine produced around 300bhp at 57,500rpm. More importantly, it developed in excess of 500ft.lb (678Nm) of torque from idle.

A CHASSIS TO COPE

With his engine problem solved, Heppenstall commissioned experienced racecar builder Bob McKee to design and build him a chassis. McKee just happened to have an existing chassis available that seemed perfect for the job. Originally used for a McKee Mk6 Can-Am car, it had just been traded in for McKee's latest model. It was a straightforward and effective spaceframe, suspended by double wishbones all round. Into this the Continental turbine engine was mounted at a slight downward angle behind the passenger compartment. Due to the design and completely flat torque curve of the engine, there was no need for a conventional gearbox, and the wastegates took over the duties of a clutch. The power was transferred to the rear wheels through a one-speed gearbox, which was also provided by Continental. To adjust the ratios to the peculiarities of each track, a McKee quickchange final drive unit was also fitted. The role of the absent reverse gear was taken over by a separate electric motor bolted to the drivetrain.

To monitor the turbine engine, a helicopter-sourced control panel was fitted, which was so tall it had to be mounted on the passenger side of the dashboard. Other than that, the interior was very basic – a brake pedal, a throttle pedal and a steering wheel were all that were needed to pilot the car.

As no off-the-shelf bodies were available, some bespoke construction was required in this area, though one corner was cut by using a Porsche 906 windscreen that was also floating about the McKee workshop. With welding wire and tape, Heppenstall mocked up the final shape of the body on the rolling chassis, and it is testament to his skills that this crude approach did actually yield a very good result. The temporary body was replaced by aluminium and glass fibre panels. In accordance with the Howmet Corporation sponsorship agreement, large sections of the Howmet-made aluminium panels were left unpainted. The first Howmet TX (Turbine Experimental) was ready for testing within five months.

In the final months of 1967, the car was subjected to extensive tests at Daytona, ahead of its debut at the 24-hour race scheduled for February the following year. The results were so encouraging that the construction of a second car was started. It was very similar to the McKee-based prototype, but with a two-inch longer wheelbase.

THE AUGUST 1970 RECORDS

Class 2
CARS OVER 500KG AND UP TO 1000KG

Standing start 1/4 mile:
11.83 seconds at 122.41km/h (76.07mph)
Standing start 1/2km:
13.48 seconds at 133.53km/h (82.97mph)
Standing start 1km:
21.18 seconds at 167.97km/h (105.61mph)

Class 3
CARS OVER 1000KG

Standing start 1/4 mile:
13.87 seconds at 104.41km/h (64.88mph)
Standing start 1/2km:
15.74 seconds at 114.35km/h (71.05mph)
Standing start 1km:
23.92 seconds at 150.50km/h (93.51mph)

Key to the car's driveability is the wastegates that control the gas flowing between the gas-generating turbine and the power-generating turbine

Despite appearances, the Howmet TX was notable for a distinct lack of noise emanating from its triple exhausts

ADMINISTRATIVE NIGGLES

Before the cars could race, however, there were some administrative niggles to iron out. The Daytona 24 Hours was part of the World Manufacturer World Championship, as were the Sebring 12 Hours and Le Mans 24 Hours. To be eligible for points, Howmet had to qualify as a manufacturer, but strictly speaking Howmet was the sponsor and McKee the constructor of the car. Here the entry of the Howmet-badged Falcon Sprint at Sebring a year earlier came to the rescue. With two cars now to their 'record' it was deemed possible to consider Howmet a proper manufacturer.

A bigger problem concerned the displacement of the turbine engine. The latest regulations stipulated that a Prototype Sports Racer could have an engine no larger than 3.0-litres. For a turbine, an equivalency factor was imposed that took into consideration the number of compressor stages and the area between the compressor, stage and combustion chamber. The only way to get an accurate measure of these elements was by looking at the blueprints of the engine. The problem was that it was a government-commissioned engine and the blueprints were therefore classified. Fortunately, the FIA representative agreed to certify the engine, though Heppenstall later revealed that the engine was actually closer to 3.3-litres in displacement than 3.0.

Fully homologated as a Group 6 Sports Racer, the Howmet TX was ready for the Daytona 24 Hours. In its class the flat eight-engined Porsche 907 was the biggest rival, while the favourite for outright victory was the Ford GT40. Piloted by Heppenstall and Ed Lowther, the TX managed to turn a lap good enough to qualify seventh in the 68-car field, and during the race ran as high as third, until a valve in the wastegate stuck open. Unfortunately, this happened just as Lowther approached the slowest corner on the track and, with the throttle wide open, he was unable to slow the car down enough to make the turn and crashed out.

At Sebring, Heppenstall and Lowther were joined by Dick Thompson behind the wheel of the Howmet. This time it qualified in an even more impressive third position, but this time the turbine blades were damaged by debris from the track during the race, resulting in a very rough running engine. This eventually caused a broken engine mount and another early retirement for the Howmet.

One of the cars was shipped to England for two events, including the BOAC 500 World Championship round at Brands Hatch. Thompson had made the trip as well and was joined for this race by Hugh Dibley who, most fittingly, was an airline pilot by trade. The eerily quiet Howmet again showed great potential and, against very strong competition, placed seventh on the grid, but was involved in an accident during the race.

WINNING STREAK

The sister car that had remained in the United States was entered in several SCCA races in the North East. At Huntsville, Heppenstall made history by securing the first ever victory of note for a turbine-engined car. in fact, he won both the preliminary and feature races that weekend. Thompson then repeated that feat at Marlboro a week later. That the team was on the right route was confirmed at the Watkins Glen round of the World Championship, where both cars were entered and both

The car's control panel came directly from a turbine-engined helicopter

Controls were otherwise very basic - brake, throttle and steering wheel

reached the finish, Thompson and Heppenstall crossing the line in third overall and first in class.

That year Le Mans was postponed to September because of the student riots, which gave the Howmet team plenty of time to prepare for the daunting task at hand. Both cars were dispatched to France - the first for Dick Thompson and Ray Heppenstall, the second for Hugh Dibley and Bob Tullius. Both cars were fitted with deflectors on the roof this time to make sure no debris could enter and damage the turbine. With such a long race ahead, getting a quick qualifying time was the least of the team's concerns and the two Howmets went on to start in 20th and 24th positions respectively.

Dibley and Tullius had a disastrous start, suffering a broken hub after only a handful of laps. A lengthy repair was required before the TX could be sent back out and, by the Sunday morning checkpoint, the car had not completed sufficient laps so was disqualified. The second car faired little better. Le Mans regulations stated that the engine should be shut off during refuelling and, as hot re-starts were not particularly beneficial to the turbine's health, the engine was damaged during one of the pit stops, limiting the car to just 100mph on the long straights. Trying to compensate for the lack of pace on the straights, Thompson overdid it going into Indianapolis and rolled the car.

> **“the first ever victory of note for a turbine-engined car”**

MEDIA ATTENTION

Even before the TX had turned a wheel in anger though, the Howmet Corporation had received enough media attention to justify the expense of the project. Heppenstall had further developments scheduled but Howmet shelved the project until, in August 1970, the car that rolled at Le Mans re-appeared with an open body, specifically prepared for record attempts at Talladega. Here the Howmet TX MkII, as it was known, set six FIA-sanctioned world records for turbine-engined cars - a glorious end for the most successful of all turbine racecars.

THE HOWMETS TODAY

After the record-breaking runs, Howmet sold the two cars to Heppenstall for $1, but without the engines, which had to be returned to Continental. Heppenstall later sold both Howmets to collectors. In the mid-1990s, the record-breaking chassis was returned to Bob McKee for a full restoration though, with a Continental engine not available, it was fitted with a Allison turbine engine instead. In 2005 the car was acquired by French enthusiast Xavier Micheron, who set about tracking down a suitable set of wastegates to make the Howmet practical again. After two years Micheron finally located some Allison wastegates and had the engine modified. The restoration was completed in 2008 and the Howmet has since been raced at Le Mans, the Nürburgring and Silverstone, and also made an appearance at the Goodwood Festival of Speed.

The second car has recently passed into the hands of Bruce Linsmeyer, who managed to scrape together enough parts to rebuild a Continental engine. He showed the fully restored car at Amelia Island in 2007, but has no plans to race it.

For all its benefits (high efficiency, low weight and lots of torque), the turbine engine in the end just had too many drawbacks to become a serious alternative to the internal combustion engine for automotive use. There may still be a future automotive purpose for the turbine engine as an auxiliary generator in the latest generation hybrid-electric cars like the Chevrolet Volt or Fisker Karma, where all the turbine's strengths can be used.

For now though, the Howmet TX has a distinct place in automotive history as the only turbine-engine car ever to win a major race.

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The quick fix?


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A discussion on the dangers of ready-made racecar simulation software

BY DANNY NOWLAN

One of the more disturbing trends I have seen emerge over the last couple of years has been the emergence of ready-made simulation. Typically, but not necessarily always, what happens is a racing series or manufacturer offers a cut-price simulation package to race teams. Typically, this has all the modelling capabilities ripped out, replaced instead with ready-made options so the user can click on various options and we all walk away happy.

This type of simulation does have its place if you need to get a rough idea of what to do. Indeed, ChassisSim has a pay-as-you-go simulation specifically tailored for club motorsport, which is very useful when you are stuck and need some direction and a rough idea of where to go. In this regard, it is very much like fast food – if you stuck in the middle of nowhere and need something to get you by, it is ideal. May I also say it whets the appetite of potential new users.

However, just like fast food, using this all the time is not a good idea and this is what we will be exploring here in greater detail. The first thing we should point out is that if you are serious about winning, you absolutely have to have the ability to edit the vehicle model, particularly in regards to aero, tyres and suspension geometry.

I should also add that from a simulation company's perspective, there's quite an attraction to ready-made simulation. You have a great deal of control on what the model is doing and can produce something very quickly. Therefore, from a commercial perspective, we at ChassisSim Technologies would be mad not to consider it. However, if you go down this road the price you pay is that you can't adopt a fit and forget vehicle model. It is something you have to work with your customers on on a constant basis, and this is exactly what we at ChassisSim would do.

To begin our discussion though, let's consider classifying the aero of the racecar. One of the attractions of ready-made simulation is that said racecar manufacturer will give you the aeromap they have either developed using CFD or the wind tunnel. In theory that's fine, but there's just one small problem. If they have screwed up the aero, said racecar manufacturer isn't going to be up front in telling you about it. Sorry folks, this is just a reflection of human nature.

Over the last three years I have been involved in a multitude of formulae and, at best, the wind tunnel data has been a rough guide, at worst, it has has been downright awful. The most extreme case of this is shown in figures 1 and 2. For confidentiality reasons I'm not going to tell you what formula this came from, but this is what I can tell you.

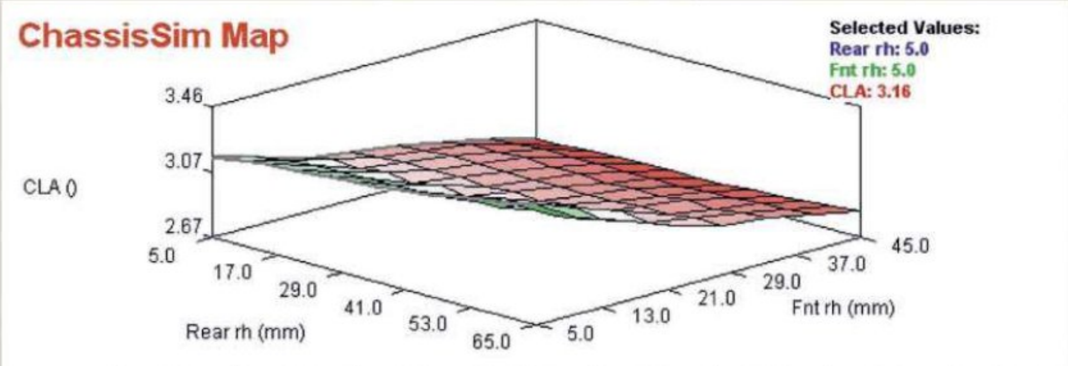
- Figure 1 is what said racecar manufacturer provided
- Figure 2 is what was generated from race data using the ChassisSim aero modelling toolbox

Figure 1 lead said race team on a wild goose chase. The creation of figure 2 was one of the keys to unlocking what the car was capable off.

As can be seen, you couldn't have had two very different aeromaps. On a humorous note, when I first encountered this car I guesstimated the aero. I then made the mistake of using figure 1... Anyway, when I went through and ran the numbers, my guesstimate was relatively close. But on a more serious note, not only is the manufacturer's map too large, it totally misses the

ChassisSim 3D Map Viewer

Downforce rh Map v3



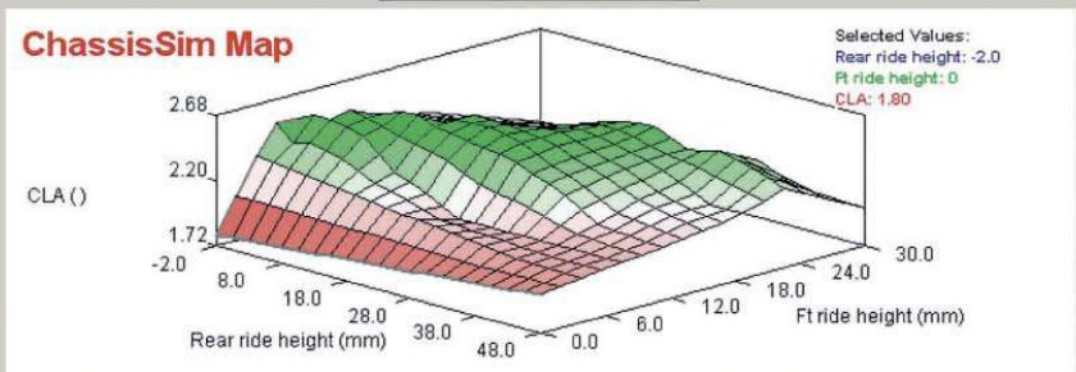
	5.0	10.7	16.4	22.1	27.9	33.6	39.3	45.0
5.0	3.163	3.08	3.00	2.97	2.93	2.87	2.81	2.74
10.0	3.18	3.10	3.04	2.98	2.94	2.91	2.83	2.75
15.0	3.21	3.12	3.03	2.99	2.96	2.90	2.84	2.76
20.0	3.22	3.12	3.05	2.98	2.95	2.91	2.84	2.77
25.0	3.23	3.13	3.03	2.99	2.95	2.90	2.84	2.77
30.0	3.24	3.14	3.06	2.98	2.94	2.90	2.84	2.77
35.0	3.25	3.14	3.03	2.99	2.94	2.89	2.84	2.77
40.0	3.27	3.17	3.07	2.98	2.94	2.91	2.84	2.77
45.0	3.29	3.17	3.06	3.00	2.94	2.90	2.85	2.78
50.0	3.31	3.17	3.08	2.99	2.95	2.92	2.86	2.79
55.0	3.34	3.24	3.14	3.05	2.95	2.91	2.87	2.80
60.0	3.37	3.21	3.12	3.02	2.98	2.93	2.87	2.82
65.0	3.40	3.24	3.15	3.05	2.97	2.94	2.89	2.83

OK | Cancel | Axes Properties/Calculator | Export text/Aero File | Import text file

Figure 1
An example of a racecar manufacturer-generated aero map

ChassisSim 3D Map Viewer

Downforce map (CLA)



	0.0	1.9	3.8	5.6	7.5	9.4	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
-2.0	1.800	2.05	2.30	2.50	2.50	2.40	2.40	2.35	2.30	2.30	2.30	2.25	2.20	2.15	2.10	2.05	2.00
0.5	1.81	2.05	2.28	2.39	2.55	2.30	2.46	2.41	2.35	2.33	2.30	2.25	2.20	2.15	2.10	2.05	2.00
3.0	1.82	2.05	2.27	2.43	2.55	2.58	2.52	2.46	2.40	2.35	2.30	2.25	2.20	2.15	2.10	2.05	2.00
5.5	1.83	2.04	2.26	2.40	2.54	2.55	2.55	2.47	2.40	2.36	2.33	2.28	2.22	2.16	2.10	2.05	2.00
8.0	1.84	2.04	2.24	2.37	2.50	2.53	2.60	2.47	2.40	2.38	2.35	2.30	2.25	2.17	2.10	2.05	2.00
10.5	1.85	2.04	2.22	2.31	2.40	2.49	2.60	2.51	2.45	2.41	2.38	2.33	2.28	2.19	2.10	2.05	2.00
13.0	1.86	2.04	2.21	2.26	2.30	2.45	2.55	2.55	2.55	2.45	2.40	2.35	2.30	2.20	2.10	2.05	2.00
15.5	1.87	2.03	2.19	2.22	2.25	2.43	2.53	2.56	2.55	2.48	2.43	2.39	2.35	2.22	2.10	2.05	2.00
18.0	1.88	2.03	2.18	2.19	2.20	2.40	2.51	2.58	2.55	2.50	2.45	2.43	2.40	2.25	2.10	2.05	2.00
20.5	1.89	2.03	2.16	2.15	2.14	2.35	2.49	2.55	2.53	2.51	2.48	2.46	2.44	2.27	2.10	2.05	2.00
23.0	1.90	2.03	2.15	2.12	2.08	2.29	2.47	2.53	2.51	2.53	2.50	2.49	2.48	2.29	2.10	2.05	2.00
25.5	1.91	2.02	2.13	2.11	2.08	2.27	2.45	2.47	2.49	2.48	2.47	2.48	2.49	2.30	2.10	2.05	2.00
28.0	1.92	2.02	2.12	2.10	2.08	2.24	2.40	2.41	2.43	2.44	2.45	2.47	2.50	2.30	2.10	2.05	2.00
30.5	1.93	2.02	2.11	2.09	2.08	2.21	2.35	2.37	2.39	2.41	2.42	2.44	2.45	2.30	2.15	2.08	2.00
33.0	1.94	2.02	2.09	2.09	2.08	2.19	2.30	2.33	2.35	2.38	2.40	2.40	2.40	2.30	2.20	2.10	2.00
35.5	1.95	2.01	2.08	2.08	2.08	2.15	2.22	2.26	2.30	2.33	2.35	2.39	2.42	2.34	2.25	2.13	2.00
38.0	1.96	2.01	2.06	2.07	2.08	2.12	2.15	2.20	2.25	2.28	2.30	2.38	2.45	2.38	2.30	2.15	2.00
40.5	1.97	2.01	2.06	2.07	2.08	2.11	2.14	2.18	2.22	2.24	2.25	2.34	2.42	2.34	2.25	2.13	2.00
43.0	1.98	2.02	2.05	2.07	2.08	2.11	2.13	2.16	2.20	2.20	2.20	2.30	2.40	2.30	2.20	2.10	2.00
45.5	1.99	2.02	2.05	2.06	2.08	2.10	2.12	2.15	2.17	2.19	2.20	2.28	2.35	2.26	2.17	2.09	2.00
48.0	2.00	2.02	2.04	2.06	2.08	2.10	2.11	2.13	2.15	2.17	2.20	2.25	2.30	2.22	2.15	2.08	2.00

OK | Cancel | Diff Axes Properties/Calculator | Export text/Aero File

Figure 2
An aeromap for the same car generated from race data

TYRE MODELLING

Figure 3

A comparison of a linear to a non-linear tyre model

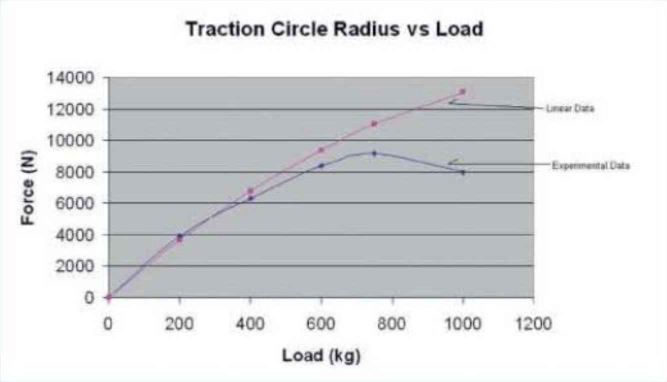
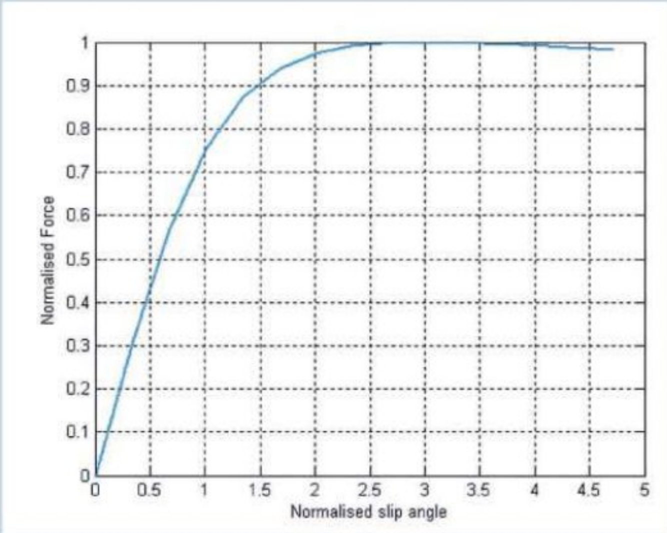


Figure 4

Pacjeka normalised slip curve



aero sweet spot of the car.

Also, to re-iterate how important it is to get the aero right, look at equation 1 (right), which estimates peak tyre load,

$$L_{MF} = \frac{wdf}{2}\cdot\left(m_t\cdot g + \tfrac{1}{2}\rho V^2 C_L A\right) + \frac{RLD_f\cdot m_t\cdot a_y\cdot g\cdot h}{tm}$$

$$L_{MR} = \frac{(1-wdf)}{2}\cdot\left(m_t\cdot g + \tfrac{1}{2}\rho V^2 C_L A\right) + \frac{(1-RLD_f)\cdot m_t\cdot a_y\cdot g\cdot h}{tm} \qquad (1)$$

Here, L_{MF} and L_{MR} are the peak tyre loads for the front and rear respectively, and C_LA is lift coefficient time area. To keep the equation simple I have fixed the aero distribution to the weight distribution. However, I invite the reader to work the numbers for different downforce coefficients. If you don't have the downforce you don't have a prayer. Furthermore, if you don't have the drag modelled right, how in the world are you going to do gear ratios?

TYRE MODELLING

The next topic we need to discuss is tyre modelling. I have already written at length on this matter in *Racecar Engineering* and, if there is one thing that is abundantly clear, it is that the race tyre is a highly non-linear and complex animal. However, most ready-made simulations typically have very strict adherence to the Pacjeka formula and, for me, this has two very important drawbacks. (Just for the record, I actually consider the Pacjeka formulation a good start, but it is just that, and not the finished product.)

The first drawback is that the peak friction coefficient of the tyre in a ready-made simulation drops off linearly as a function of load. Also, more often than not, said tyre model is temperature invariant. Any of us who have had any experience with real racing tyres knows they are horribly non-linear and temperature dependant. To illustrate this, consider this comparison of traction circle radius of a linear tyre model vs a tyre model that was produced using actual race data. This is plotted as a function of load.

As can be seen very clearly from figure 3, the linear tyre model is woefully inadequate when it comes to describing what the tyre is actually doing. This has massive ramifications when it comes to determining the combination of springs, bars and dampers you need.

The second drawback of tyre models used in ready-made simulation is the tyre force vs slip angle / slip ratio characteristic uses a strict Pacjeka formulation. I know I've shown this before in previous articles, but to make the point I shall show it again here. Consider this plot of normalised force vs slip angle.

My two big reservations with this curve are what the tyre is doing in the post-slip regime, and how it behaves in the lead up to this. If this is truly what the tyre is doing then fair enough. But I think we all know from experience that if this curve truly applied, why would we be concerned about oversteer or understeer if the force factor drops to 0.9? Again, I offer the invitation to someone who is well versed in the Pacjeka model to come forward and explain this.

This has massive implications for how a car responds on the edge. Let me illustrate this mathematically. Tyre force can be approximated by,

$$F_y = fn(\alpha)\cdot fn(L,T) \qquad (2)$$

Where α is slip angle, L is tyre load, T is temperature and F_y is lateral tyre force. To keep the discussion simple I've lumped the camber and traction ellipse terms into fn(L,T). At a given slip angle then, the derivative of the tyre force with respect to slip angle is given by,

$$\frac{\partial F_y}{\partial\alpha} = \frac{\partial fn(\alpha)}{\partial\alpha}\cdot fn(L,T) \qquad (3)$$

These derivatives are critical in classifying the handling characteristics of the racecar, and $\delta f/\delta\alpha$ is the slope of the curve we saw in figure 4. My point is that if you don't have that modelled correctly there is no way you can make meaningful adjustments on the car. The problem with ready-made simulation is that you don't get a choice, you are stuck with what you have been given.

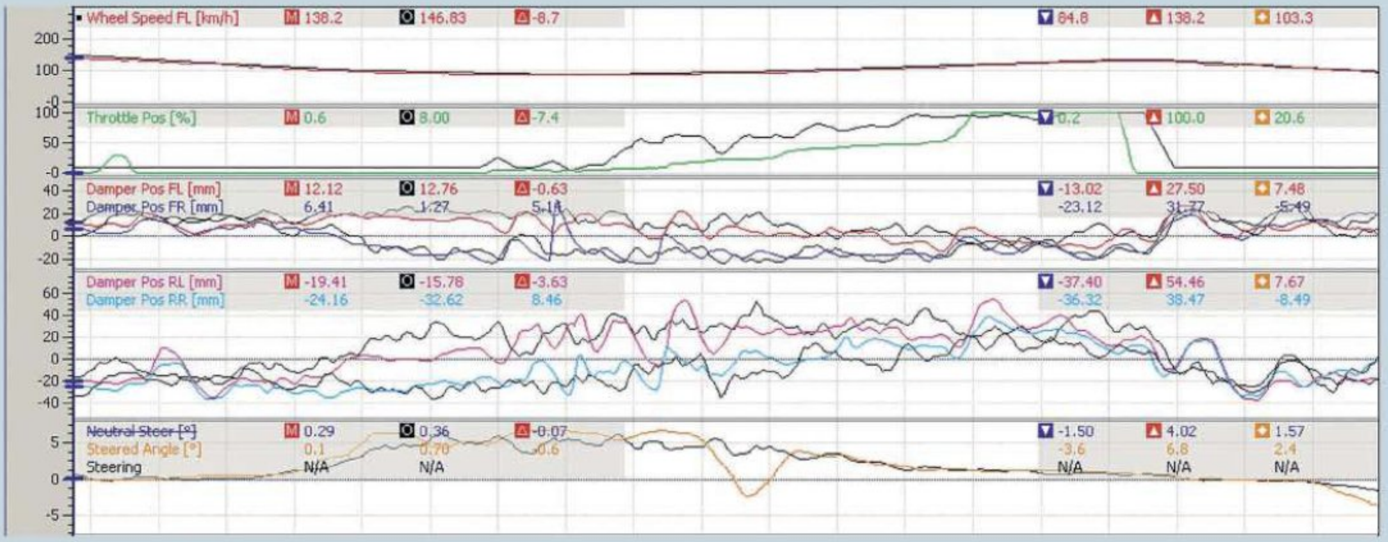
But the question has to be asked where is a good place to start with tyre modelling? After all, there are no hard and fast rules. This is why I wrote an article on tyre modelling from nothing. Another good place to start though is if you have good tyre test data. However, that does vary between different tyre manufacturers.

Also, let me offer some perspective based on modelling all manor of racecars and being involved in developing simulation software. I have said it before

REAL VS SIMULATED DATA

Figure 5

Actual data vs ChassisSim simulated data



and I will say it again, the perfect tyre model doesn't exist. We have some pretty good approximations of what the tyre is, but it isn't perfect. Consequently, as you learn more about your racecar you will always be tweaking the tyre model to some degree. And as with any endeavour, what you knew last year will be different to what you know today, so the ability to incorporate that into your vehicle model is vital. Ready-made simulation takes this vital functionality away from you.

SUSPENSION GEOMETRY

The next area I want to discuss is suspension geometry because, as with tyres, this can have a massive impact on the car modelling. The suspension geometry dictates how the forces are transmitted into the sprung mass. They also dictate the motion ratios. If you get the motion ratios wrong, any spring changes you are evaluating might as well be irrelevant. I will illustrate this by presenting some motion ratio results for a spec formula I worked in. For confidentiality reasons, I've normalised the ratios, but what I will present is what the series quoted and what I measured, as shown in table 1.

The reader will note that I have included measured sq. The

TABLE 1

Comparison of quoted vs actual motion ratios

	Quoted	Measured	Measured sq
Front	1	1.01	1.025
Rear	1	0.97	0.941

reason I have done this is the wheel rate, as the rate the tyre sees is in fact M.R^2*spring rate. As can be seen, the fronts are okay. However, while the rears aren't disastrous, they are at a point where inaccuracies can start to creep in, particularly when we start to get to the outer ranges of the spring adjustments. This has massive implications when considering what ride heights to run, or when calculating static roll distribution.

Furthermore, while it is a tedious job measuring the suspension geometry on a racecar, it is also a straightforward job. Yes, it is time consuming, but the rewards are more than worth it. It also gives you peace of mind because you have confidence in knowing that what you have seen is what you get. To further reinforce this, look at this approximation for the lateral load distribution taken on the front axle:

$$prr = (wdf*rcf + prm*hsm)/h \quad (4)$$

Here prr is the lateral load transfer taken at the front, wdf is the front weight distribution and prm*hsm is a function of spring and bar rates, suspension geometry and weight distribution. My point is equation (4) quantifies the effect of what happens if someone hasn't done a good job of measuring the geometry. Unfortunately, ready-made simulation also bypasses all this. Given the impact this can have on roll distribution, relying on someone to do your hard work for you isn't such a good idea because you have no idea where the numbers have come from.

Finally, remember this point on using simulation. I have always maintained that simulated laps are the full stop at the end of the process, but the real power of simulation lies in the fact that it forces you to consider every aspect of how every component of the car works. This is the thing that takes your racec engineering to the next level. With ready-made simulation you are robbed of this process.

My last reservation with ready-made simulation is that most ready-made lap time simulation is typically pseudo static as opposed to transient. I realise here that I could be stepping on quite a few toes but, as far as I am concerned, while pseudo-static simulation can point you in the right direction, it simply cannot finish the job. To illustrate this, consider the example of a ChassisSim simulated lap vs an actual lap, as shown in figure 5, above.

The top trace is speed, the following trace is throttle, the third trace is front dampers, the fourth trace is rear dampers and the last trace is steering angle. To make this more interesting I'm asking you to guess which is simulated and which is real. What I will tell you is that there are no grip factors here. However, what is abundantly clear from both the front and rear damper traces is that trying to approximate this by assuming the circuit is smooth is simply not accurate. The dampers alone are moving in the order of +/-20mm, which has a massive impact on where the roll centres and cambers are, as will as leading to variations in tyre loads. My point is if you are not taking things like this into account, how can you hope to set up your racecar accurately?

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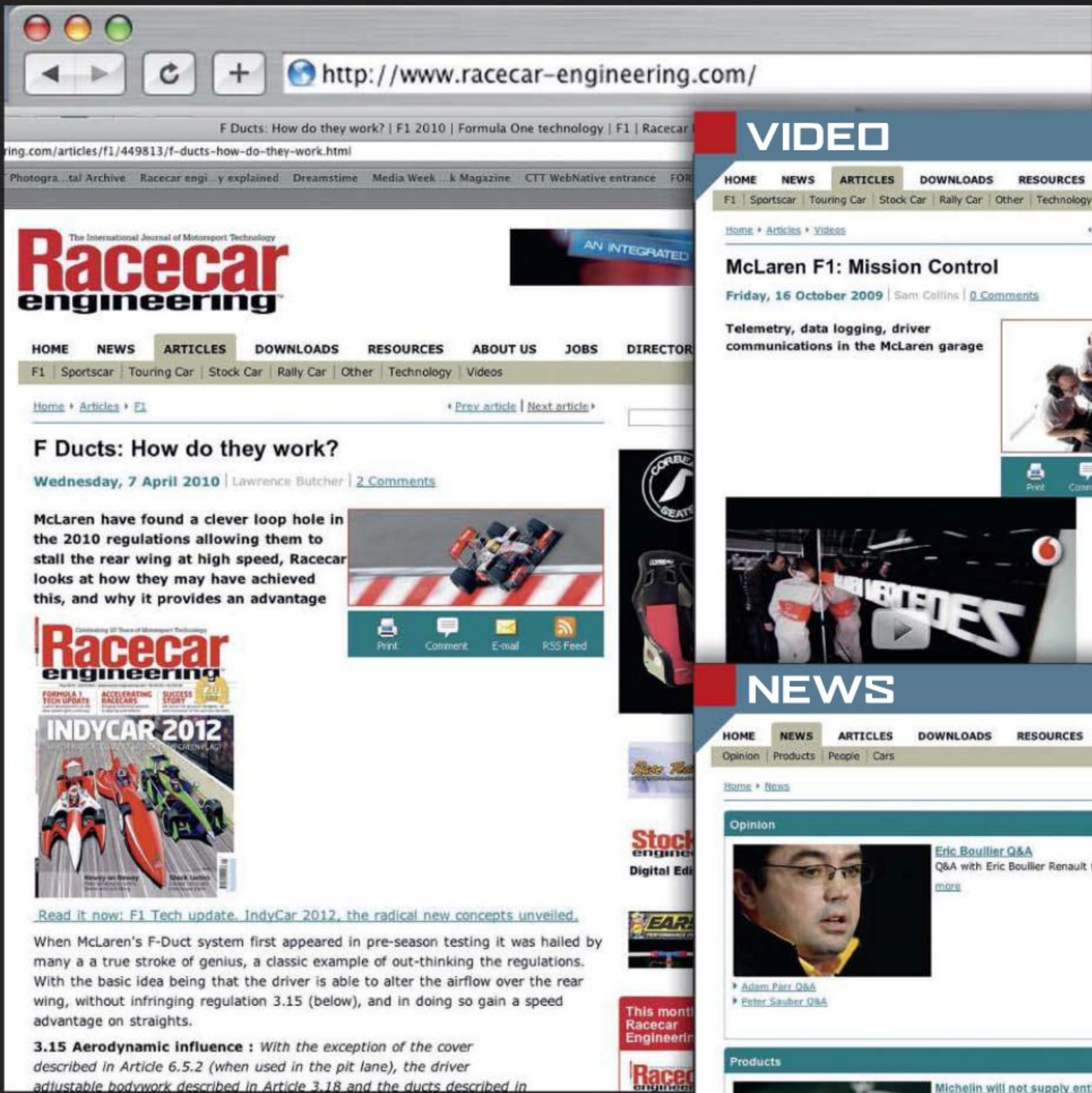

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RACING GREENER

Eco-speed

Environmentally-conscious motorsport is turning to the question of performance

MIA LONG BEACH 'GREEN' CONFERENCE 2010

BY IAN WAGSTAFF

The business of energy efficient motorsport has reached a maturity that enabled the Motorsport Industry Association (MIA), in association with the Specialty Equipment Market Association (SEMA), to call its latest conference – held on the Friday of the Long Beach Grand Prix – 'The Race Has Gone Green'. SEMA's John Waraniak said it was even about time we stopped using the term 'green', but then the five drivers who, at the end of the conference were announced as the American Le Mans Series energy efficiency ambassadors, all wore blazers that made them look like refugees from the Augusta Masters.

Meanwhile, Chris Aylett of the MIA pointed out that the conference now had more of a commercial and less of a technical bias, and it certainly seemed a long way from the association's first such meeting in Birmingham some years ago. Performance and Racing Industry consultant Don Taylor pointed out just how much has happened since the MIA first took its energy efficient conference concept to Long Beach. 'When we started 'green' racing it was an oxymoron but, in the last 12 months, so much has happened.

'Primarily, the ethos has changed. To most people hybrid means the Toyota Prius. But,' asked Taylor, 'how many modified Prius have you seen?' However, such as KERS in F1 and the Zytek 09SH hybrid have helped change the perception of the hybrid and now Porsche and Ferrari are introducing petrol/electric hybrids. At some point, predicted Taylor, there may even be hybrid 'muscle' cars...

Likewise, electric vehicles used to mean golf carts but, thanks to such as Teslar, attitudes are changing about electric performance, too.

The association with SEMA led to Aylett stating that what is being achieved by motorsport is not only affecting the OEMs but also the automotive aftermarket as a whole. He believes the rule makers will make it difficult for the industry to make 'green' racecars, but it can still be a development partner for the OEMs. 'But, I am not yet sure how we can engage with the mainstream,' he said. Jamie Allison, director North America Motorsports, Ford agreed that the relationship 'has ebbed and flowed' while, as key note speaker, Mazda's Robert Davis was able to indicate his company's commitment. Aylett went on to say that 'what is happening is a most exciting development for the aftermarket... Developments must be both commercially and socially acceptable, but we are being pushed ever closer to the tuning market.'

Lola managing director, Robin Brundle, pointed out that universities are now engaged with the problem and have 'no inhibitions', and that his company is now recycling carbon and working with educational establishments to see how it can be brought back to its original shape.

> **If we have electric racing it must be more like NASCAR, with banging and barging**
> **PETER DIGBY, XTRAC**

Alongside all this, there was some technical content to the day. The problem, said Allison, is about sustainability and range extension. 'Imagine running the Indy 500 on one 'charge',' he said. Though such fanciful ideas were brought back down to earth by Indy Racing League senior technical director, Les Mactaggart, who stated what many were undoubtedly thinking: 'We must not lose sight of the entertainment. It is important that we don't forget the fact that racing must be thrilling.'

Hybrid Porsche in Veranstaltergemeinschaft Langstreckenpokal Nürburgring

Scott Atherton addressed just this when he spoke of the problem of sound, or rather lack of it, with electric racing. 'One of the defining elements of motorsport is the sound we can hear now,' he said, referring to the practice session taking place outside the conference hall. 'I don't think the sport can take this lightly.' Atherton also spoke of a possible solution he had seen at Clemson University, where a group of engineering students are working on integrating a 'sound-by-wire' sound system into a vehicle.

Xtrac managing director, Peter Digby, wondered how important sound really was. 'I don't see less people turning up at Le Mans because the Audi and Peugeot diesels are quiet,' he opined. What he reckoned was crucial was the racing itself. 'If we have electric racing it must be more like NASCAR, with banging and barging.'

Asked whether ALMS was likely to embrace electric, Atherton pointed out that the organisation had already been approached by several manufacturers wanting to run an electric series as a support to the ALMS, adding that since the ALMS had started promoting 'green' technology it has seen sponsor interest from categories not interested in racing before, including non-motorsport media.

Green racing technology may have become just another facet of the industry but it still needs to be driven. And for that reason the ALMS is sending David Brabham, Paul Drayson, Johnny O'Connell, Chris Dyson and Gunnar Jeanette out into the world to promote the message – hopefully without those lurid green blazers.

Missed something?

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BRIEFLY...

LOLA QUITS F1
Lola has announced it is abandoning its 2011 Formula 1 programme. It will continue with its Sportcar and customer chassis programmes, as well as offering R&D facilities to both the motorsport and defence industries.

CUSTOMER CAR(E)
Audi Sport has opened a dedicated customer sport centre in Ingolstadt, Germany. Initially it will focus on supporting teams using its R8 LMS racecar. The 950m² facility includes a parts warehouse, exhibition area and offices.

SEE SHELL
Oil giant Shell has signed up to continue to supply the Ferrari Formula 1 team with its fuel and lubricants for the next five seasons. The company celebrated its 450th start with Ferrari at the Australian Grand Prix earlier this year.

BED TESTING
Miguel Fragoso, the managing director at Millbrook, has told *Racecar Engineering* that it is one of his 'personal commitments' to increase the amount of motorsport testing being carried out at the Bedfordshire proving ground. He admits the issue of noise is a problem, but says the track has many facilities, including handling and off-road tracks that are not affected by this, and is also undertaking work on 'green' technology. 'I am convinced we are going to find synergies with the racing teams,' he said. 'I am working on a plan but we have to respect the sensitivities of the local community.'

CLARIFICATION
In *RE* V20N5 we featured a toolbox made by F1 Tools. Please note that the lifetime warranty is on the tools only.

THE BUSINESS

Life after recession

CHRIS AYLETT

Are your troubles really over?

With the new British government now in place, we must re-focus on recovering from the worst recession in living memory. But many motorsport firms are caught in a dilemma. If the economy dips, they will struggle to grow sales, get paid and keep trading. If it recovers, surprisingly, the chance of failure can actually increase, and history shows that more firms fail coming out of recession than going into it, as working capital is stretched to breaking point.

It is good to know that buoyancy is returning at the sharp end of business though. Small and medium-size businesses (SMEs) are better placed to react to fast changing economic conditions than their larger counterparts.

Motorsport businesses were fast to react when the recession kicked in and they will undoubtedly be quicker to respond now that some optimism is returning. SMEs are the wealth creators and job makers, accounting for 85 per cent of economic growth in the UK, according to the experts. However, uncertainty is making life hard for them. There is uncertainty following the recent election and whether their banks will support them. More than half suffered late payments throughout 2009 and this picture continues, meaning businesses are caught between supplier pressure for early payment and customers who are paying later. Many resort to withholding in-demand goods until they are paid – a wise precaution in the motorsport business.

Small companies are able to be flexible though and this is a vital benefit. Business may increase five per cent one month and dip 10 per cent the next, and only those that can handle this will survive. To do this, companies have to be ready to expand or reduce at short notice, whether in staff or financial resources.

> **"SMEs will spearhead business recovery"**

SMEs will spearhead business recovery. The MIA has lobbied hard for the new UK government to give them a break and not suffocate them with bureaucracy, legislation and taxation. There is talk of giving a tax free start-up period for new companies, and encouraging recruitment with subsidised training and apprenticeships. Some hot tips from the experts confirm the following:

- Remember that turbulence creates change and change creates opportunity.
- If your financial arrangements may limit growth then sort this out early – don't get to the point of needing cash to fulfil orders before speaking to your bank.
- Don't stop planning ahead and looking at new markets, but avoid taking big risks.
- Cash flow forecasting is critical. Do it week by week, and forecast seasonal peaks and troughs to make sure the flow of cash is well under control.
- Focus on those distinct qualities of your products that give you pricing power.
- Make selective acquisitions so that you can out-perform your rivals.
- Some businesses fail, so some customers are not being supplied and doors that were shut will open.

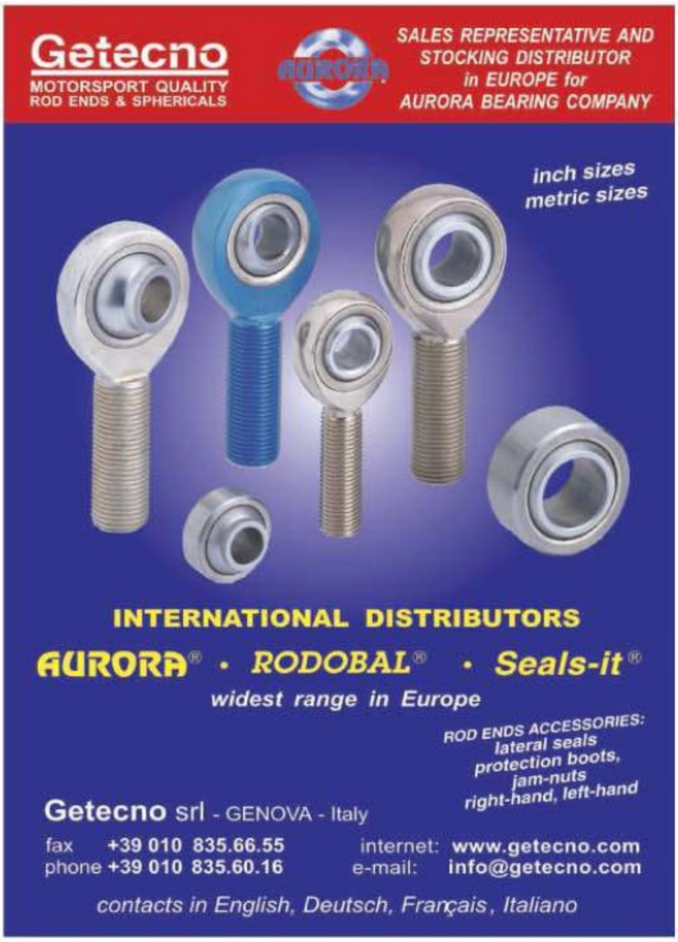
Whatever you do, don't retreat into your shell. You will have to fight harder to secure the same sales as before, but you will come out of the recession stronger. The first and best opportunities in motorsport will probably be linked to growth in consumer spending in the USA, before any other market. The USA motorsport market is the largest and the most diverse in the world, so keep an eye on developments in that country before all others.

Finally, check out www.the-mia.com for details of their business development visit to NASCAR and IndyCar between 21 and 29 May. This is the best introduction to these opportunities in this growing market to beat the recession.

LAT

The US motorsport market is the biggest in the world

Chris Aylett is CEO of the Motorsport Industry Association www.the-mia.com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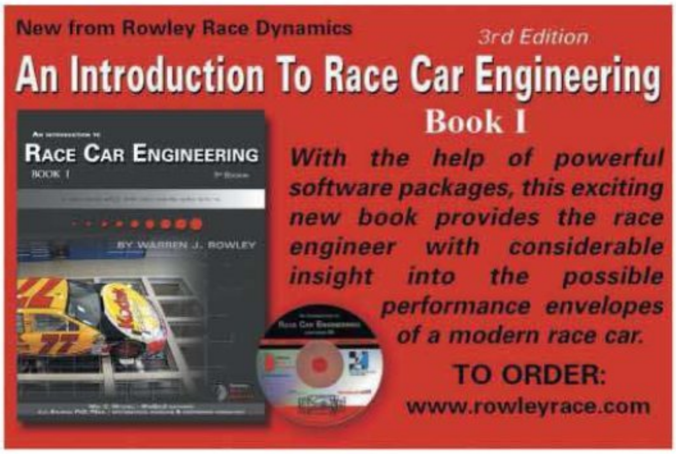

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info@gems.co.uk
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INTERCOMP
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ISAAC INSTRUMENTS INC
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LONGACRE
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MOTOR SPORT ELEC
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PI RESEARCH
T: +44 (0) 1954 253600
QUANTUM SUSPENSION
T: +44 (0) 1243 865 058
RACE DATA ENGINEERING
T: USA (+1) 714 449 1445

STACK
T: +44 (0) 1869 240404
10 Wedgwood Road, Bicester, Oxon OX26 4UL
www.stackltd.com
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ENGINE MANAGEMENT SYSTEMS

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MOTEC
T: AUSTRALIA (+61) 3 9761 5050
MOTEC
T: JAPAN (+81) 489 46 1734
MOTEC SYSTEMS
T: USA (+1) 714 897 6804
OLE BUHL
T: +44 (0) 1425 478 822
PRECISION RACE SERVICES
T: USA (+1) 248 844 1060
SUPERCHIPS
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TREVOR MORRIS ENG
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WALBRO ENGINE MANAGEMENT
T: USA (+1) 989 872 7091

ENGINE SENSORS

KULITE SENSORS
T: +44 (0) 1256 461646
MAGCANICA INC
T: USA (+1) 858 454 8950

PENNY & GILES
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15 AIRFIELD ROAD, CHRISTCHURCH, BH23 3TG, UK
F: +44 (0) 1202 409 475
www.pennyandgiles.com
sales@pennyandgiles.com

Variohm-EuroSensor Limited
T: 01327 351004
Williams Barns, Tiffield Road Towcester, Northants, NN12 6HP
F: 01327 353564
sales@variohm.com
www.variohm.com

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T: New Zealand +64 2596 5599
REGENT
T: +44 (0) 1908 612602
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T: Sweden +46 8532 55890

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Dino Paoli S.R.L
T: +39 (0) 522 300 828
Via Guido Dorso, 542100, Reggio Emilia, Italy
F: +39 (0) 522 304 864
www.paolipitstop.com
info@dinopaoli.com

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COMPAIR UK
T: +44 (0) 1494 465000 / +44 (0) 1473602222

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AWNING COMPANY
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TECTONICS UK
T: +44 (0) 1962 736316
TOP MARQUEES
T: +44 (0) 1623 740777

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T: +44 (0) 121 766 5544
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OLD HALL PERFORMANCE LTD
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T: USA (+1) 615 832 6355

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MAGNAFLUX
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MECHANICAL SIMULATION CORPORATION
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www.carsim.com/racecar_engineering

D.A.T.A.S
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Wheler Road, Seven Stars Industrial Estate, CV3 4LB, England
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Via Cesare Della Chiesa, 21, 41100 Modena, Italy
www.crptechnology.com

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USA - 4005 Dearborn Place, NW, Concord, NC 28027
www.bmrs.net

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F: +44 (0) 1869 245500

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CASTROL
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HD6 3DP
Fax: +44 (0) 1484 721263
enquiries@millersoils.co.uk
Web: www.millersoils-online.co.uk

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T: USA (+1) 713 932 9954
STP
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T: USA (+1) 305 771 1010
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T: USA (+1) 919 480 0905

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FUEL CELLS

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alexahfabs@fairadsl.co.uk.
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1 Patriot Drive, Rooksley, Milton Keynes, Buckinghamshire MK13 8PU, England
www.atlltd.com
atl@atlltd.com

ATL RACING FUEL CELLS USA
Spear Road Industrial Park, Ramsey, New Jersey, USA
T: USA(+1) 204 825 1400
F: USA(+1) 201 825 1962

EARS MOTORSPORTS
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T: USA (+1) 541 923 6005
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www.fhsracing.co.uk
info@fhsracing.co.uk
F: +44 (0) 1753 513050

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F: +44 (0) 1753 513050

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www.krontec.de

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SFS PERFORMANCE
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FUEL LINES

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matt@thinkauto.com

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XRP INC
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rsteele@moog.com
T: Martin Jones +44 (0) 1684 278218 mjones@moog.com
www.moog.co.uk/industrial/motorsport
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Lola Cars International Ltd
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Huntingdon, Cambridgeshire PE29 7DS
United Kingdom
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www.lolacars.com

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PILBEAM
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F: + 44 (0)1933 676519

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Krefelder Straße 320
41066 Mönchengladbach, Germany
www.capricorngroup.de
sales@capricorngroup.de
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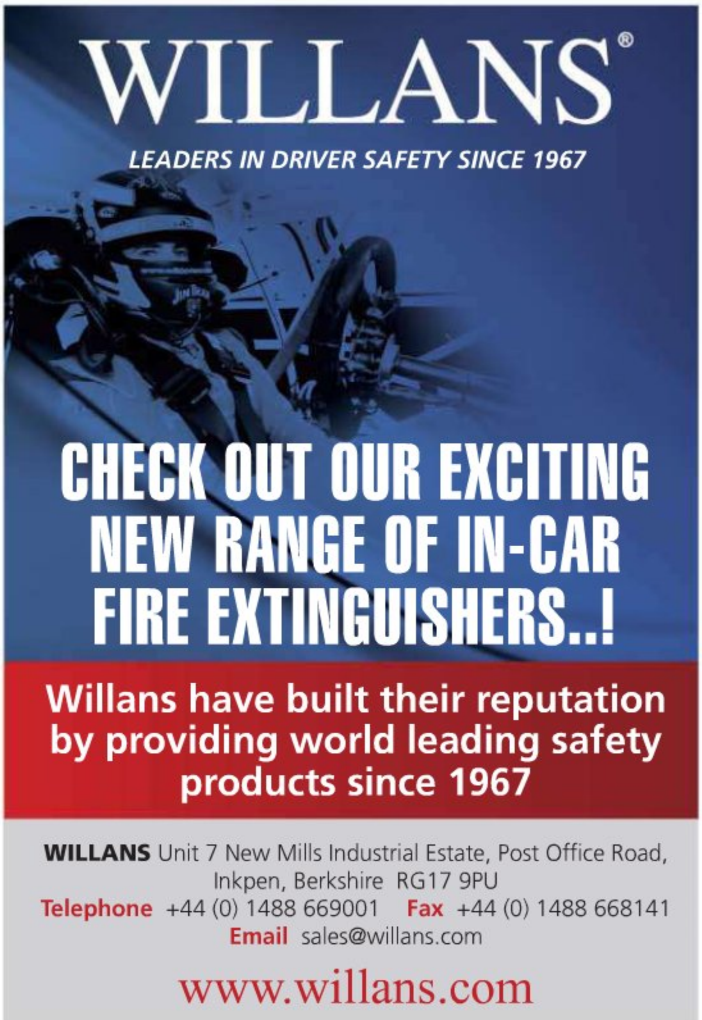
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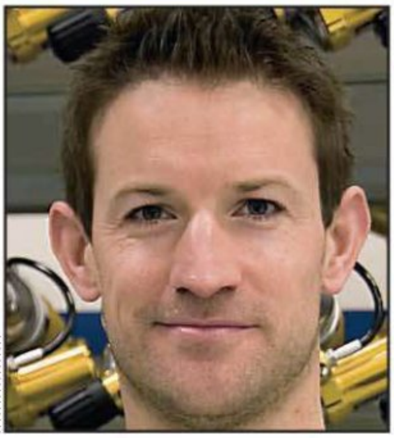
CHRIS WITTER
THE INTERVIEW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How much of your work is motorsport related and what areas of motorsport do you supply?
In relation to what I'm doing at the moment, the time it's taking up in a day, I'd say it was about 60 per cent motorsport related. As far as the car side of motorsport is concerned [Öhlins is also heavily involved in motorcycle racing - see below] I am unable to discuss the Formula 1 work, but we are involved with it, and many other things, too... In the British Touring Car Championships we supply a number of the teams, including all the BMWs, because we actually supply to BMW Motorsport. We're also on the Hondas with Team Dynamics, we're on the Chevrolets with RML and we're pretty much on most of the top running cars.

We're also involved in rallying, too. We're very fortunate that we're working with Prodrive in that area, that's one of our key customers. In fact, the new Group N car for this year is spec'd on Öhlins dampers.

What products do you offer to the motorsport market?
Well, our latest products are the TTX dampers, which are twin tube forms of damper. And we have got various types depending on the application. So if it's for a Touring Car, then it's a MacPherson strut-type damper on the front, while on the rear it's just a standard telescopic damper. For single seaters it's the standard telescopic type.
The twin tube means you have a pressure balance in the damper. It's a more balanced set up, so it gives a better response than the single tube dampers. There are a number of features to our dampers that we believe make them an improvement over those offered by some of our competitors, but the main advantages are quality control and the fact that all the parts are held to a higher tolerance, so you get a better consistency and performance from the damper. The materials are also of a better specification.

CHRIS WITTER, BUSINESS DEVELOPMENT MANAGER, ÖHLINS
- **1991-1996:** apprentice with Austin Healy race specialist Dennis Welch Motorsport
- **1997-2000:** Engineering degree at Liverpool University
- **2000:** MSc in Motorsport Engineering and Management at Cranfield University
- **2000-2008:** technical sales engineer at Performance Friction
- **2009:** distributor for Project Mu brakes
- **Present day:** Öhlins business development manager for the UK and Ireland

How big a part do motorcycles play in Öhlins' business?
'Bikes are actually about 90 per cent of our business. This is the amazing thing. You look in the car world and you see we're on things like the Peugeot and the Audi in the Le Mans Series and then in Touring Cars, so a lot of people look at us and say, 'well, we're obviously doing really well in cars'. But when you look at the sales of the company, cars is only about 10 per cent of the total business, so in fact 'bikes is our core activity.

So are you looking to expand the business on the car side then?
Yes, but I've really got to give the two areas equal priority because the 'bikes are our bread and butter. However, we are looking to grow the car side of the market. And not just the racing side, we've also brought onboard a new road and track programme, and we're marketing our products to club racers and road users who want to take their cars out on track, for instance. Then there's the OEM work for companies like Triumph, Norton and Lotus.

RACE MOVES

Gil de Ferran, the co-owner and managing partner of IndyCar team Luczo Dragon Racing / de Ferran Motorsports, has been elected the teams' representative on the advisory committee that has been given the job of researching, reviewing and recommending the next generation chassis and engine combination for the Indy Racing League.

Malcolm Wilson, founder and CEO of Ford WRC team M-Sport, has been elected to the executive committee of the Motorsport Industry Association (MIA). **Iain Wight**, business development director (motorsport) at Ricardo, has also been elected to the committee, while **Jim Morris**, of Lifeline Fire and Safety Systems, has been elected vice chairman.


LAT
Malcolm Wilson

17 motorsport engineers from five different countries have graduated from the Spanish METCA Specialised Masters in Motorsport course. The graduates were handed their certificates at the Epsilon Euskadi base in Vitoria, and the event was presided over by **Joan Villadelprat**, Epsilon's president, and Iosu Zabala, Mondragon University's Rector. The Spanish Automobile Federation's president, **Carlos Gracia**, was also in attendance.


LAT
Tony Fernandez

Lotus Formula 1 team principal, **Tony Fernandes**, has been awarded with an honorary degree from the Universiti Teknologi Malaysia. The degree, which is for business innovation, was awarded for 'contributions to the country, academic excellence and society'.

Geoff Jones, who is the new director and partner of Sports and Entertainment Limited (SEL), the company that owns 25 per cent of V8 Supercars Australia, is to fill Tony Cochrane's shoes as executive chairman of the championship, while the latter takes a three-month break away from Australia's premier race series. Jones, who was formerly Gold Coast Indy boss, joined SEL at the beginning of April, and is the first partner the company has taken on in 13 years.

RACE MOVES

Alan McKechnie, a well-known race team owner in the 1960s and '70s, has died at the age of 72. McKechnie was confined to a wheelchair after being hit by a virus when he was just 22 and was well known for having supported many young drivers during his career, including world champion **Nigel Mansell** and tin top legends **Andy Rouse** and **Barrie Williams**.

Nick Heidfeld

LAT

Nick Heidfeld, currently the reserve driver with the Mercedes F1 team, has been appointed chairman of the Grand Prix Drivers' Association (GPDA). Heidfeld takes over from **Pedro de la Rosa**, now a full-time driver with Sauber, continuing a trend for reserve drivers to hold the post.

Sebastian Vettel and **Felipe Massa** have both been named as GPDA directors.

US race track operating giant International, Speedway Corporation, has promoted two of its personnel at its Kansas Speedway facility. **Jeff Boerger**, former president at the track, has been named president of Kansas Speedway Development Corporation, while **Pat Warren** has taken his place as president of the Speedway.

Butch Hylton

LAT

Butch Hylton has been named crew chief for Kevin Harvick Inc's no 2 Chevrolet in the NASCAR Truck Series. Hylton succeeds **Doug George**, who switched to **Ron Hornaday's** no 33 Chevrolet earlier in the season.

James Key has now taken over the role of technical director at the BMW-Sauber Formula 1 team. Key, who has joined Sauber from Force India, replaces **Willy Rampf** in the position. Rampf has stepped down after 10 years as technical director with the Swiss organisation and 14 years with the team in total.

Kyle Busch scored his first victory as a team owner at the Nashville NASCAR Truck Series encounter, which was also just his fourth start in the pick-up championship. 'It's a big deal,' he said, 'a lot of blood, sweat and tears were put into this over the winter.'

UK race commentator **Norman Greenway**, a one-time BBC radio Formula 1 commentator who was also well known for his commentary work at Snetterton and Brands Hatch, has died at the age of 87. The former Jim Russell Racing PR man once auditioned for the role of BBC TV grand prix commentator, but lost out to a certain **Murray Walker**.

Richard Branson

LAT

Richard Branson has admitted that he very nearly bought the Brawn team before it was snapped up by Mercedes at the end of last year. The Virgin boss has since formed his own brand new Formula 1 team alongside Manor's **John Booth**.

Luca Di Montezemelo has announced that he will step down as chairman of the FIAT

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CHRIS WITTER
THE INTERVIEW

CONTINUED

Q How does Öhlins test its dampers?
We have damper dynos in Sweden [where the company originated and is based], so everything gets tested in house before it is released to market. But then, of course, you're also dependent on any feedback you get from the customer too, because what you see on a dyno is not necessarily what you see on track. That's why it's so important to have engineers who are working with the teams, to have this technical partnership with the teams and to understand how it is actually functioning on the track, as well as on the dyno.

Q Are there any recent technical developments we should know about?
We're really putting a lot of effort into our mechatronic system right now. These are effectively electronically-controlled dampers. These are actually banned in a lot of forms of racing, but what we're seeing now is interest from the standard road bikes we're starting to work with, people like Ducati for example. The latest Ducati Multistrada is coming out on mechatronic dampers, and that should then filter through to the sports bikes, and that should then go through to the Superstocks. Regulations will then have to change because, if a standard road bike has got it on, it will have to be permitted in racing. So it's almost like coming in through the back door, because normally you would think things are pioneered in motorsport and then passed down to the road side, but what we're actually doing is developing it for the road so that we can get it introduced into the race side. With the mechatronic dampers we can't enter them into motorsport on the cars because of the regulations, but if the development is there ready, we've got everything in place should regulations change.

This is a frustrating aspect of motorsport. If you look at the pull out of BMW from F1, one of the reasons the company gave is that they felt they couldn't develop certain technologies. Motorsport, because of the current regulations to drive costs down, is losing the freedom to be pioneering with the cars, so of course now there are things coming out on the road side before they're coming out in motorsport. A prime example of that is this mechatronic system.

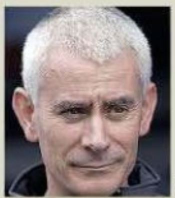
A staple in motorcycle racing, Witter says Öhlins dampers are looking to expand further into the motorsport market

RACE MOVES

group, although he will retain his position as chairman of Ferrari. During his tenure, di Montezemelo helped steer FIAT through the economic downturn and was pivotal in the company acquiring a 20 per cent stake in Chrysler in 2009.

team with immediate effect. The FIA has said that Symonds would be free to return to grand prix racing in 2012. However, the FIA deal means he can work for any F1 team as a consultant through his Neutrino Dynamics company.

di Montezemelo LAT



Geoff Willis LAT

Martin Whitmarsh has been appointed as CEO of the McLaren Group and deputy chairman of McLaren Automotive. Neither role will affect his position as team principal of the company's F1 outfit.

Geoff Willis has joined the newly formed Hispania Racing Team as technical director, a role he previously held at Red Bull Racing.

Tiff Daniels LAT

Martin Whitmarsh LAT

F1 Racing Magazine technical editor and former Renault F1 technical director, **Pat Symonds**, has reached a settlement with the FIA and will be able to work as a consultant for any grand prix

Tiff Daniels, support engineer for Earnhardt Ganassi Racing's NASCAR Sprint Cup Series teams and Late Model racer is leaving EGR to pursue her racing career. In addition to racing, Daniels will be undertaking both television and radio broadcasting work.

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

YELLOW FLAG

Safe technology

KEVIN BORRAS

What's in it for motorsport? Everything

The eSafety Challenge, the subject of our previous two columns, is fast approaching, and we're in the midst of inviting members of the press from all over Europe to attend. Quite often the reply is 'What's in it for us?', especially when we are talking to motorsport titles. The answer is quite simple: what's in it for you is to see at first hand the correlation between motorsport's safety technology and the safety technology that finds its way into road cars. It doesn't matter if you are driving a Ferrari F1 car at 240mph at Monza or pootling along at 30mph in a Nissan Micra on the outskirts of Stevenage, the drivers need to know two things. If they have an accident, that they'll be able to walk away from it or, even better, that the car will be able to warn them of pending danger or help them avoid it altogether.

> "vehicle manufacturers take their safety cues from the racing fraternity"

A lot of the potentially life-saving technology that will be demonstrated at the Millbrook test facility in Bedfordshire, UK on 13 July has its roots in motorsport. There's no doubt that vehicle manufacturers take their safety cues from the racing fraternity but the eSafety Challenge will provide conclusive evidence of that, if indeed it were needed.

Telematics is not a new development, it's been the subject of many an article in the field of advanced traffic management publications, and in reality it's nothing more than the exchange of information between two computers. What's that if not a diagnostic information dump by a racecar? Or how about speed cameras, which for all intents and purposes are a road safety measure – they were invented by a Dutch racing driver in the late 1950s called Maus Gatsonides so he could record his lap times more accurately. The links are many and varied, but the majority of the six technologies on display at Millbrook (ESC, Emergency Braking, Blind Spot Monitoring, Lane Support, Speed Alert and Adaptive Headlights) have their foundations in your world – motorsport.

Although the event is by invitation only, the Challenge's organisers, the FIA Foundation, are offering two *Racecar Engineering* readers the chance to win an invitation to the event. All you need to do is email *RE*'s deputy editor, Sam Collins (racecar@ipcmedia.com), with the answer to this simple question. The first two out of the hat will receive an invitation to attend the 2010 eSafety Challenge on 13 July and the chance to meet eight times Le Mans 24 Hour champion Tom Kristensen and 2008 F1 champion Lewis Hamilton.
That question: what does the abbreviation ESC stand for?"

Kevin Borras is editor of Thinking Highways *and publishing director of H³B Media, the media partner for the 2010 eSafety Challenge. For more information go to www.esafetychallenge.eu and www.thinkinghighways.com*

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GRAVEL TRAP

I have seen the future...

A few weeks ago on a lighthearted radio show I called McLaren 'the Cylons of Formula 1'. At the time, I didn't know how right I was. For those who do not watch the sci-fi channel, the Cylons are the cybernetic bad guys in the science fiction TV show *Battlestar Galactica*. These robotic villains are fully networked and everything they make, see or do is shared.

On a recent tour of the staggering McLaren Technology Centre in Woking, England Julien Feyeux, an engineer from one of the team's partners, PLM implementation specialist Processia, told me about its work in Formula 1. As we walked through the spotless machine shop where the staff were working away to drawings stuck on the side of the various tools, Feyeux casually pointed at the printed illustrations. 'Eventually we will do away with those,' he said, 'as soon as you print it is out of date and then errors can slip in. We want to see screens at every work station.'

> "the part will arrive before you even knew you needed it"

Imagine there was a component failure on a car – at the touch of a button you could trace every piece of data related to it: full data for every lap it has run; when it was fitted and who by; right back through the manufacturing process to what CAD work was done on it, by whom and even at what time of day the work was done. With everything networked, the car will be capable of telling the mechanics what components will need replacing, what has had an excessive loading too many times and anything else they might want to know. Everything would be logged from the moment the first CAD drawing is made, through DOE, development, manufacture, use and eventually failure or disposal. An operator can then get as little or as much out of it as he needs to.

As futuristic as this might sound, it is not a pipe dream. All the technology already exists, though there is some more integration work still to be done. Yet Feyeux claimed that we are unlikely to see a company with total PLM for at least five years (and that's for McLaren-sized companies, it could be as much as 10 years for EADS-sized ones). Why? 'Technology not only encompasses hardware and software, but also people, and many have done things in a way that works for them for many years and it will take time to educate them about the new way of working.'

Last month Charles Armstrong-Wilson wrote how he felt PLM was a waste of time for a small concern, claiming it was not the future for motorsport as it does not move fast enough for our industry.

But, from where I sit, even small teams can benefit from total PLM. Once the system is installed on a car, it will handle set-up sheets, data acquisition, component lifing and even procurement. The future PLM package could even start to behave like a price comparison website – when a part needs to be re-stocked or is coming to the end of its life, it could automatically search the internet and interrogate component suppliers for the most cost-effective part. No more 'phone calls asking about getting stock in a hurry, your entire bill of materials could be created and ordered automatically, so the part will arrive before you even knew you needed it.

For me it is clear that total integration of PLM will increase reliability and shorten development time. But, for that to happen, the Charles' and many others in the industry need to accept that.

DEPUTY EDITOR
Sam Collins

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The Porsche 911 GT3 RSR, using track-leading technology from ZF Sachs, earned the Le Mans Series GT2 class championship this season. The new Sachs Racing 4-way adjustable through-rod dampers, along with the brand-new, super lightweight Sachs Racing Carbon Clutch kept the GT3 RSR at the front of the pack all season long.
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