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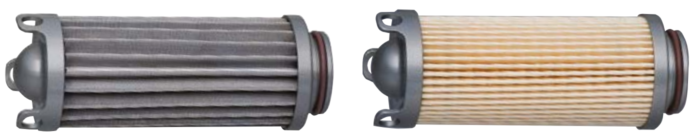

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Who said electricity and water don't mix? The Formula E Championship visited New York in July and despite a soggy start the event was considered a success

Who let the cogs out?

How gears have been giving engineers a mechanical advantage for centuries

The engineer's quiver of systems and structures borrows heavily from nature. After all it surrounds us, and any inquisitive mind will take lessons and ponder about it. The way a tree grows is driven by nature's strict adherence to the laws of thermodynamics, with the added goad of utilising the minimum amount of inputs required to produce the results.

This includes the raw materials, the chemical reason how chlorophyll cycle extracts the energy from sunlight to produce wood, which brings us to structures and the earliest known plants to have grown wood, approximately 395 to 400 million years ago. Natural selection produced therefore a final iteration, which seems to work pretty well.

So we can say engineering can use the careful observation of nature to produce whatever artefact we need to perform a given task. But there would seem to be some aspects of engineering that would not fit the previous sweeping statement. Like wheels and gears, not commonly observed in nature, thus being the brilliant product of the human mind.

Cog-ito ergo sum

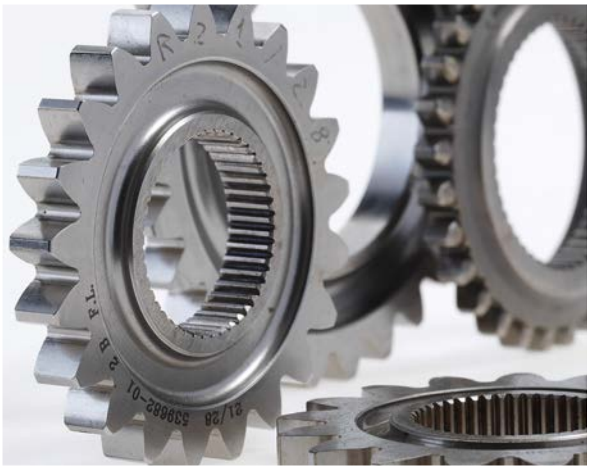
Natural selection would explain why wheels are not in nature's solutions to the problem of locomotion: a partially evolved wheel, missing one or more key components, would probably not impart an advantage to an organism. There is a possible exception to this in the flagellum, a freely rotating propulsive system in biology, but it seems to have been arrived at by exaptation. If so inclined you could use it in a theological argument; that an intelligent creator, not limited by evolution, would be expected to deploy wheels wherever they would be of use.

Ravished by the sheer implausibility of that last statement we can delve into the evolution of gearing. Gears can be considered one of the oldest machines known to mankind; their origin can be traced to around about the third century BC. A Chinese engineer, Ma Jun, built a vehicle with two wheels and a geared linkage connected to an indicator, which pointed to the south no matter how the chariot was directed.

Then there was the Antikythera mechanism, an example of a very early and intricate geared device, designed to calculate astronomical positions with more than 30 gears arranged in a complex differential gear train. It was used to mechanically calculate the position of the sun and moon. Archaeologists date its manufacture to around 80 BC, but this astronomical device's complexity is far greater than anything else previously ascribed to that time period, and the gear train it uses is certainly more sophisticated than anything described in the literature of the period.

Early engineers used gears for hoisting heavy loads such as building materials, because of their force-multiplying properties. The mechanical advantage of gears was also used for ship anchor hoists and catapult pre-tensioning.

For a long period after these discoveries, there was a hiatus and there were no major developments concerning wheels until the 17th century, when the first attempts to provide constant velocity ratios (conjugate profiles) was recorded.



A simple cog, when interacting with another cog, can change speed, torque and direction of power. They look quite nice, too

The very earliest gears can be shown to be a wheel with cylindrical cogs, usually stubs of wood sticking out of the rim actuating another wheel with slots meshing with the cogs. Examples of these were used, typically, with animal, wind and water powered machinery to increase the rotational speed and couple them to mills, pumps, textile machines, etc., usually lubricated with animal fat grease.

Gearing up

The industrial revolution in Britain in the 18th century saw an explosion in the use of metal gearing. A science of gear design and manufacture rapidly developed through the 19th century.

The 19th century also saw the first use of form cutters and rotating cutters and in 1835 Whitworth in England patented the first ever gear hobbing process. Several other patents followed until 1897, when Herman Pfauter of Germany invented the first hobbing machine that was capable of cutting both spur and helical gears.

Through the 20th century various types of machines developed and the next major step came in 1975, when the Pfauter company introduced the first NC hobbing machine and, in 1982, the full 6-axis machine was introduced. We are now used to working with external, internal, spur, helical spiral bevels, hypoid crown, worm, epicyclical or even rack and pinions, which transform rotational to linear movement or vice versa.

Selection 'box

A cogwheel, more commonly known as a gear, is a rotating machine part having cut cogs, or gears, which mesh with another toothed part to transmit torque. The mechanism can change the speed, torque, and direction of power. If not a one-to-one ratio they produce a change in torque, creating a mechanical advantage, so may be considered a simple machine. The teeth on the two meshing gears all have the same shape, now evolved into two or more meshing gears, working in a sequence called a gear train or a transmission. A gear can mesh with a linear toothed part, called a rack, thereby producing translation instead of rotation.

The gears in a transmission are analogous to the wheels in a crossed belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage.

As a friend who worked in gearboxes said 'People will only speak of gearboxes when they go wrong.' And properly using your gears to keep the engine in its sweet spot and matching speeds between the engine and the gear you had selected was an art in itself, that drivers had to master. This was, of course, before the paddleshift, where slabs of silicon carry the code that makes sure everything works seamlessly, protecting dogs, gears and driveshaft's from shocks.

The most usual program all racing engineers have to write early in their career seems to be a gear ratio and chart program to examine the tractive effort curve and the best selection of gears for a given track and engine. They will also find it is difficult to do anything to the ratios that will give you more than a couple of tenths of lap time.

But before we leave gears, there is actually an example of gearing in nature after all: the Issus coleoptratus, an insect less than 2.5mm long, which can jump at 400g in two milliseconds.

The industrial revolution saw an explosion in the use of metal gearing

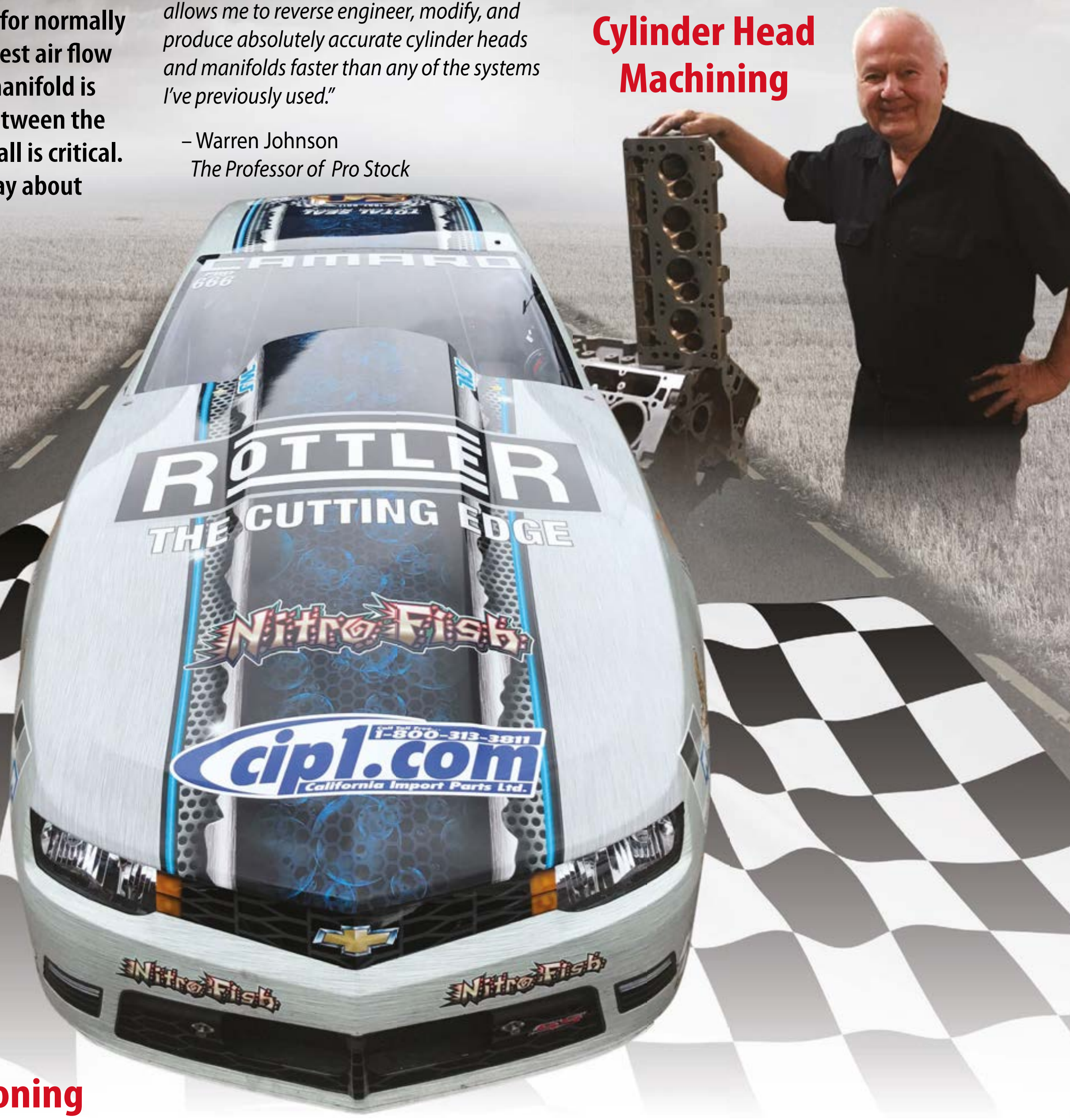
Hear from the Experts!

Pro Stock drag race engines are the pinnacle of engineering for normally aspirated engines. The best air flow through the ports and manifold is critical. A perfect seal between the rings and the cylinder wall is critical. Hear what the experts say about their Rottler machines:

"The Rottler P69 with its advanced software allows me to reverse engineer, modify, and produce absolutely accurate cylinder heads and manifolds faster than any of the systems I've previously used."

– Warren Johnson
The Professor of Pro Stock

Rottler CNC Cylinder Head Machining



Rottler CNC Engine Block Honing

"We have spent countless hours using the Rottler CNC Vertical Honing Machine in the hunt for the proper surface finishes required to achieve perfect ring seal.

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The vitrified stones gave us nice clean cuts and make it easy to hit the target surface finish numbers but consumable costs are much higher compared to diamond stones.

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After testing CBN abrasives from Ed Kiebler of Rottler, I was amazed at the surface texture, we now have the best of both worlds.

We have an abrasive with extremely long life and a surface finish that is as good as or better than the vitrified delivered. Little to no debris, no burnishing and almost thread like consistency in the valleys.

We've examined these different abrasives and the surface textures they leave under high power microscope and the results are consistently the same. CBN honing stones are a real game changer."

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The sting in the fail

Could Toyota's Le Mans debacle be down to it not 'designing for failure'?

Designing for failure, rather than designing purely for success, may seem an odd approach, but to my mind not doing this was the cause of Toyota's challenge disappointingly falling apart before even half-distance at this year's Le Mans, despite it having taken – at last – the strategic decision to enter three instead of two cars.

The move to three cars was expensive, but still it fitted to the old adage at Le Mans; one to crash, one to break down, one to win. In such an extreme high-speed endurance event, the car and powertrain design team must imagine that not everything will go to plan, no matter how meticulous the preparation. Therefore, foreseeing potential pitfalls and building-in a defence against them should be part of the overall design and management philosophy.

Punctures are a strong likelihood during the 24 hours with the debris that inevitably builds up. What makes this a particular issue is the near 14km lap length. Getting back to the pits with a flat tyre, especially if it should require almost a complete lap as in the case of Lapierre's Toyota, can prove to be impossible due to the damage caused by the battering of the flailing carcass. Incorporating some tough containment of the tyre's remains and protecting key items such as the loom that was damaged and caused this car's retirement should not be beyond the capabilities of the engineers concerned.

XPB

Did Toyota pay the price for not preparing thoroughly for car damage, from clouting kerbs for instance, at this year's Le Mans 24-hour race?

Start-stop race

Then there was the clutch that failed after uphill restarts on the ICE, this being the apparent reason for the Kobayashi car retirement. Presumably a weight-saving and packaging decision, the design did not allow for multiple combustion engine starts rather than an MGU start. It should not have been beyond the imagination of the design team to envisage a situation such as an engine restart after an incident on track, with the battery capacity low. After all, the car has two propulsion systems incorporated in it; why make one totally reliant on the other just to get going? Should a more robust clutch not be fitted, write a code such that, should the car stop on track, the engine shuts off, giving the driver the only option of restarting on electric power alone.

Then, of course, there was the two hours necessary to change the front MGU assembly, compounded by having to change the battery as well in order to do so. It could have been envisaged, surely, that such a failure could happen and serviceability better taken into account. One of the reasons that Audi enjoyed so much success was its ability to repair its cars from seemingly impossible damage in record time – this seems to have become overlooked recently.

Porsche also almost lost the race for the same reason, but in its case it wasn't necessary to change the battery in order to get at the MGU of its racecar. Result? One hour's delay instead of two and the resultant, if lucky, race victory.

It's complicated

Does this mean that the LMP1H cars are just too technically complicated for 24-hour racing, especially with the transformation of the race strategy in recent years from running at a quick but measured pace to an outright sprint all through? I think that this is partially true, and the ACO should have foreseen this were it not quite so obsessed with demonstrating advanced hybrid technology.

This year, the ACO was nearly and embarrassingly caught out. A more gradual introduction of the different hybrid features would have been wiser. However, I'm not convinced that either Porsche or Toyota, despite their many hours of off-season reliability running, sufficiently tested for the actual race conditions that can occur. It has been mooted that a lot of slow running in very hot conditions due to safety cars and slow zones might have contributed to lack of reliability. Although there were no signs of this affecting the LMP2 or GT cars, these do not have the complex powertrains of the LMP1-H racers.

More likely is that drivers continually hitting kerbs and running off-track, including through gravel, occurs only during the race. Therefore the testing doesn't cover this and the shorter events leading up to Le Mans may not show up such weaknesses either. Given, however, that the engineers are creating a racing car, not a tank, this is more down to team management and driver discipline. As an example, albeit from the GTE class, had I been the relevant team manager seeing one Ford driver deliberately take to the grass, with all the risks of punctures etc, to try to pass his team-mate mid-way through, it would have had me waving a hammer at him from the pit wall in the best Alfred Neubauer tradition.

On the level

Porsche admitting that it felt forced to run its new pre-chamber combustion engines close to the limit came as a surprise. One simply cannot afford, surely, to take any chances on such a vital part of the car, any failure of this being virtually certain to cause retirement – which was the fate of its other car. Another point to consider is where the cars test – Paul Ricard and Portimao are favoured destinations and are at plus 400m above sea level. Le Mans is at sea level, and puts a whole new pressure on the engine. Porsche says that if it took a second out of the engine and out of the hybrid system, it would be 'bulletproof', but the level of competition from Toyota meant that it had to push the boundaries, and that then led to failures.

Perhaps, with just two manufacturers now and Porsche entering only a pair of cars, some backtracking of treating Le Mans as a sprint race all through is needed. One can understand that fear of a rival team actually running flat-out and reliably (as Toyota so nearly managed last year) must affect thinking, but time carrying out repairs in the garage is almost always greater than can ever be saved in faster lap times. Maybe the strategy of having a 'hare' intended to race flat-out, and the other, more bullet-proof, car to run conservatively as a backup needs re-introduction. An easier decision though when one has three cars to bring into play – allowing two hares.

It should not have been beyond the imagination of the Toyota design team to envisage a situation such as an engine restart after an incident on track

Bullseye

The Red Bull second team has once again hit the mark with a first class chassis – *Racecar* puts Toro Rosso's innovative STR12 under the microscope

By SAM COLLINS

Scuderia Toro Rosso was founded in late 2005 after Red Bull acquired the tiny cash-strapped Minardi Formula 1 team from Paul Stoddart. The primary aim of the re-named outfit from that point on was to develop young drivers for the main Red Bull Racing team and, as such, from its foundation until the 2010 season the team relied on modified Red Bull Racing chassis.

However, in 2010 the practice of using customer chassis was banned and the team had to develop its own designs from scratch. Yet despite the focus of the team remaining on driver development, it has since then gained a reputation for creating innovative designs over the last seven seasons, especially under the leadership of James Key – who has been technical director at Toro Rosso since 2012. The team's 2017 car, the Toro Rosso STR12, does nothing but add to this reputation.

The STR12 made its track debut during a private test in Italy shortly before making its public debut in Barcelona ahead of pre-season testing. When the covers came off the new design it was clear that the Toro Rosso team had identified the same general car concept as Mercedes (which had launched its 2017 model a few days earlier), leading many in the motorsport press to claim that the STR12 was simply a 'blue Mercedes' or that it was at the very least 'Mercedes-inspired'. This is something that clearly grates with Key.

'Because we launched our car after Mercedes everyone assumed that we had copied them, though I'm sure if the launches had been in the reverse order they would probably still say the same,' Key says. 'We were kind of sad that we were not the only people to come up with some of the different things on the car.'

Toro argento?

But the fact remains that the design of the STR12 is clearly visually similar to that of the Mercedes W08 in some areas, though it has a notably shorter wheelbase. But it is worth noting that only Mercedes and Toro Rosso have pursued this car concept in 2017. Both cars feature a narrow ducted nose, for example, though the Toro Rosso uses a neat array of NACA ducts on the underside, while the Mercedes uses a large scoop. Both also feature large ducts on

‘Everyone wants to be closer to Mercedes and Ferrari, but I would like to be a bit closer to Red Bull’

The STR12 shares some design traits with the Mercedes W08, although the Toro Rosso has a notably shorter wheelbase

the roll hoop with different segments supplying air not only to the 1.6-litre V6 engine but also to coolers mounted in the centre of the car. It was Toro Rosso which introduced this centreline cooling concept to F1 in 2014, something other teams (including Mercedes) have since copied. It allows the cars to run with smaller sidepods, with the aim of improving the car’s aerodynamic performance. The ERS cooling, as well as some other coolers, are located centrally on the STR12, with charge air coolers located in the sidepods.

Key is keen to highlight the fact that the similarities between the Mercedes and the STR12 is just a coincidence, as the two groups of engineers independently identified the same design directions. ‘What we did, probably like everyone, is an exhaustive amount of simulation work to try and figure out what we could expect from a 2017 car. It wasn’t just how much downforce we could get and things like that, it was all the nuances, the possible variations of how the tyres could work. That was one of the biggest difficulties, to try and figure out what the basic balances to target should be, as we knew they could be different from last year in terms of aero balance, and weight distribution, for example, even though that only has a one per cent range by regulation. But you have to base your architecture around something.’

Early development

Work on the STR12 actually started in late 2015, before the 2016 car had even been built, but more importantly it was before the new regulations had been finalised. Crucial details of the rules, including the overall aero package, tyre size and even the size of the fuel tank were only finalised during the 2016 season. ‘It was very difficult to come up with a car concept because of the rules being late and the lack of tyre data,’ Key says. ‘You had no data for it at all, because your decisions are based on where you think you can get to, where you would like to be on a particular path, in terms of raw performance, then you look at your previous strengths and weaknesses. But with the new rules we had none of that to go on for this car.’

Even once the technical regulations were finally published there was still a lot of uncertainty about many areas, and that left every team with a significant challenge to

'There is still a big advantage with making your own gearbox, it means you have complete freedom in terms of the transmission casing and inboard suspension'

overcome. 'As it was all so speculative, we had to build some adjustment into the car,' Key says. 'In the first year of a new rulebook you find yourself asking do you just need to go all out on certain things with the subtleties following later, or do you spread across the map to reduce risk? In our case we didn't want to have particularly peaky sensitivities in terms of aero, we didn't want a very limited range of mechanical balance options. Because you have no baseline you have to accommodate it much more than you normally would. So that all goes into building up the concept, but there are still the basic engineering beliefs in what is right and wrong. Once you get to a concept you need to validate it for downforce, for different L/D figures, or grippier tyres than you expected, and things like that, you have to adapt those ideas. Everything becomes a trade-off.

'In parallel to that we tried to get an understanding of how much performance it was possible to gain,' Key adds. 'That gives us an ideal world, and that sets some idea of what you think is possible and what will be competitive, even if you never get there. It gives you a high bar to target for mechanical grip and aero performance.'

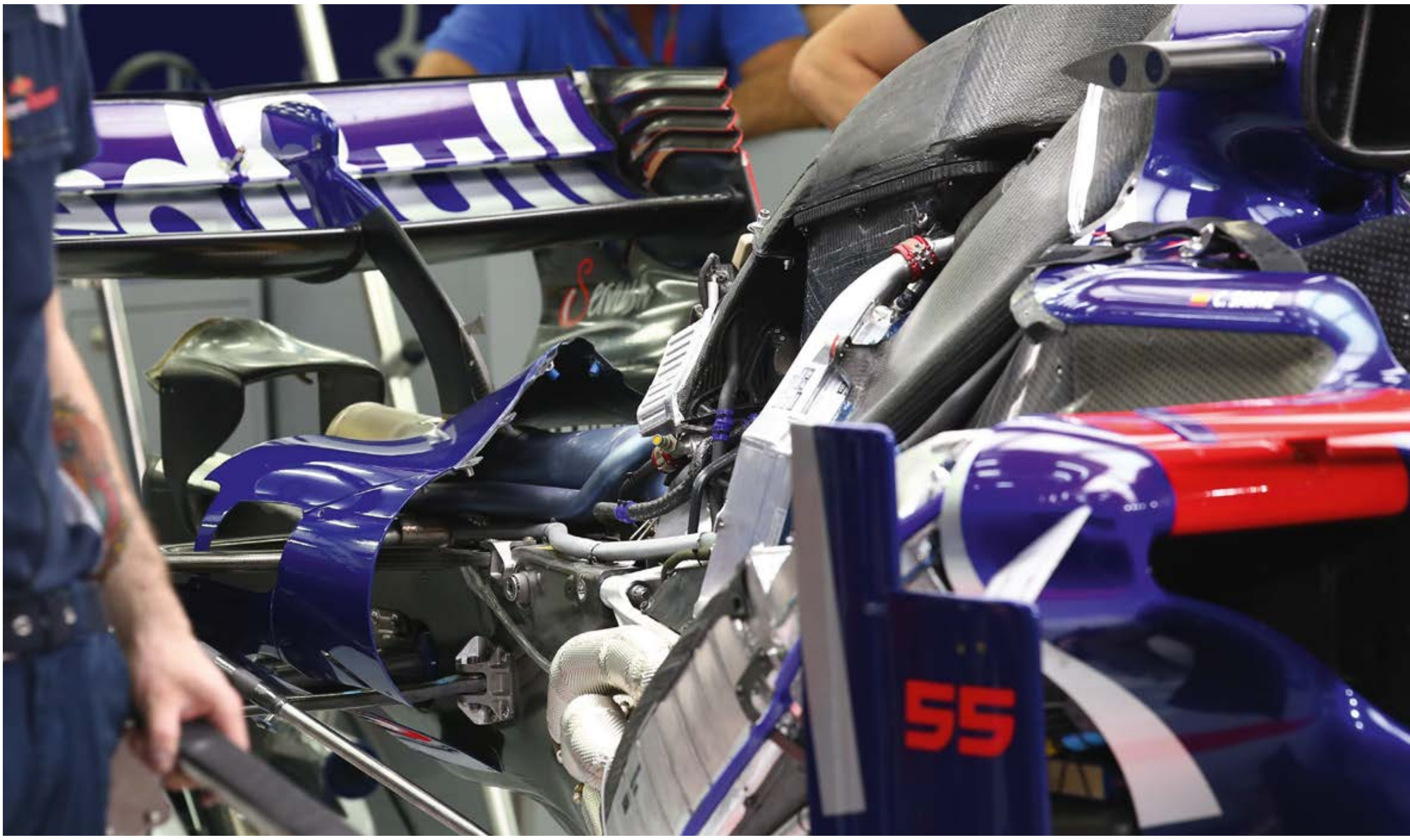
STR12 uses an unconventional front wishbone attachment. The wishbone actually ends slightly short of the upright and an extension then reaches outwards and rearwards to meet it. It is reminiscent of the Lotus 49 suspension layout from the '60s

Into the void

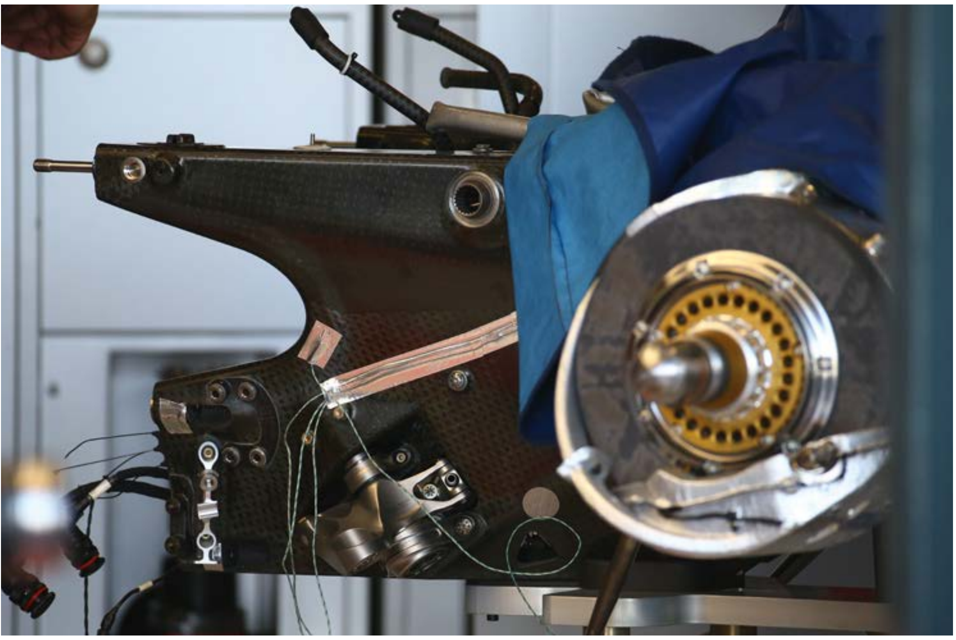
One of the biggest uncertainties surrounded the tyres. Pirelli had been unable to test its new product on a representative car until winter testing in early 2017,which meant that the data supplied to teams was based purely on simulation and assumption.

'It's been down to the tyre engineering groups to work out what a tyre of this size will really do, with their great expertise and the information they have about compounds and construction,' Key says. 'Much of it is black magic to me. They work out what performance they think it will give, what balance it needs to work, how sensitive it is to vertical load. I have to say our guys did a really good job of that as our predictions were not so far off what we found the tyres to actually be.'

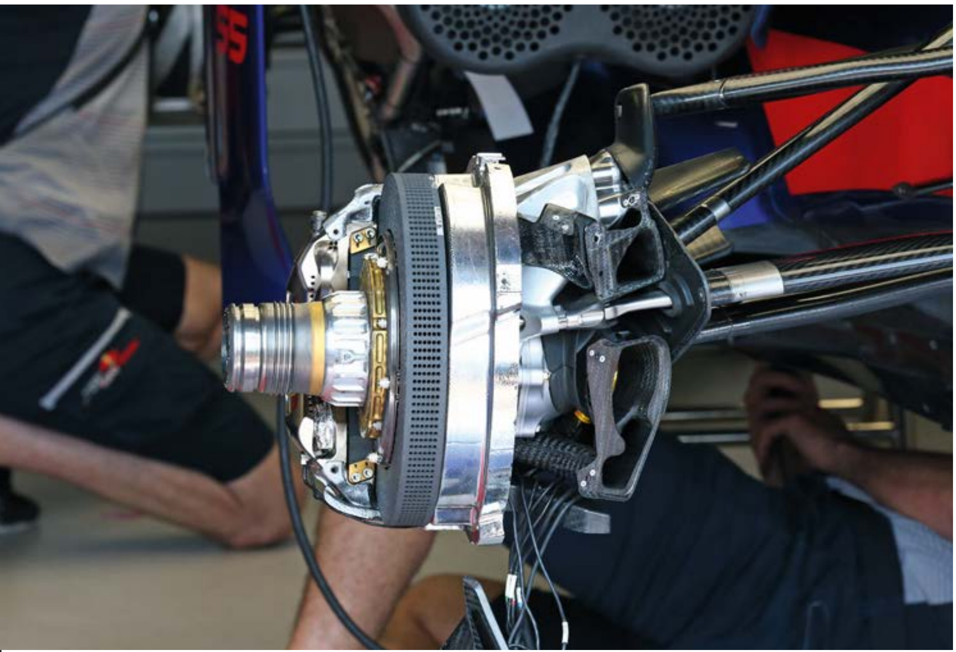
But as the work was based on predictions, and educated guesswork, the car's designers had to take that into account. 'It meant we had



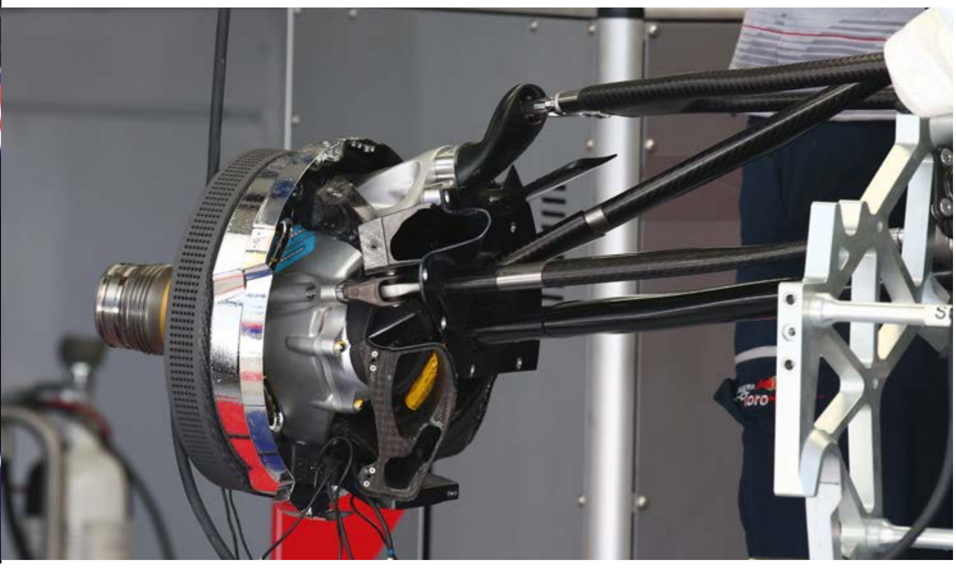
Bodywork removed to show the charge air cooler in the sidepod. Other coolers in centre of car allows it to run with smaller sidepods, with the aim of improving the aero performance



Toro Rosso manufactures its own carbon fibre transmission casing, with gearbox internals produced by Xtrac



Brakes are carbon-carbon and applied with Brembo calipers. STR produces its own brake by wire system



The upper wishbone and upright. Note how wishbone mounting is in double shear, a belt and braces approach

It was clear that the Toro Rosso team had identified the same general car concept as Mercedes

to design in a bit of flexibility in terms of the range of tools on the car,' Key says. 'If we found that the tyres gave a massive front limitation, or the opposite, or the high speed to low speed balances were very different, we knew we would have to have the tools to be able to dial that out. Profile is important in the mechanical sense in terms of contact patch and migration of the shape and everything like that, and you can make gains there with experience and the right base models. That is what our guys did.'

Flexi-Bull

As wind tunnel testing of the STR12 began at Toro Rosso's facility in England before the tyre size was confirmed, let alone the tyre shape, the design also had to be flexible in other ways. 'You have to take a few guesses. If you have a load condition for a tyre and it has a certain profile, then at a certain pressure you get a shape, and from that shape you can guess at things, but it is very speculative,' Key says. 'Tyre profiles are massive in terms of aero so from an aerodynamic perspective that means you have to desensitise yourself to tyre profile, which is not really an optimal thing to do. But it means that you don't end up with something unexpected.'

With larger tyres and a substantially higher level of downforce the cornering speeds have substantially increased in 2017, and that then puts much higher loads through the racecar, especially its suspension members, but as a result of the uncertainty surrounding tyre performance there was also uncertainty around the exact levels of loading that various components would have to withstand.

Fully loaded

'All your load levels are higher for longer,' Key says. 'Look at start performance for example: you have bigger contact patches so you have something with higher static friction levels to try and get away off the line, and you also have more weight in the car, so all the suspension, gearbox and chassis load cases change, the same for cornering and braking. But as there was no historical data to work with, we again had to simulate a best guess of what the peak performance was likely to be, which means simulating what you expect to see at the end of the 2017 season. But you don't want to make things bigger and heavier than they need to be.'

This work on calculating the loads was not only crucial in ensuring that the structures

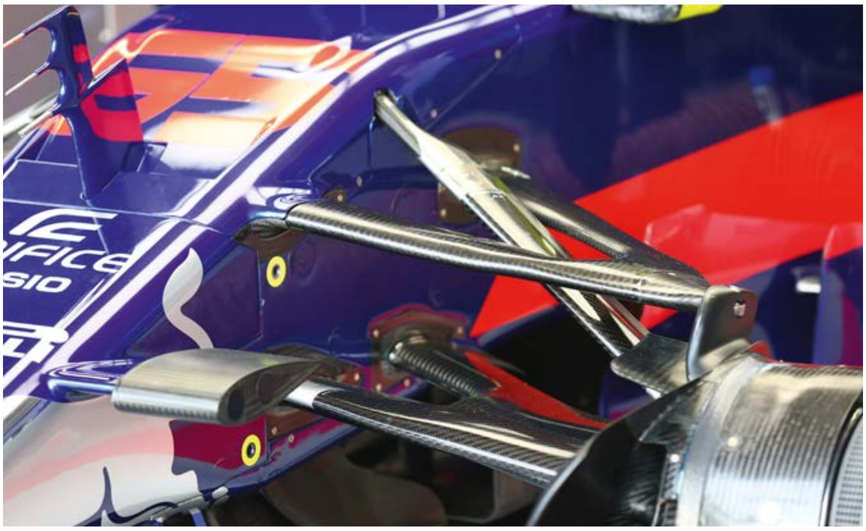
Work on this year's Toro Rosso STR12 actually started in late 2015, before the 2016 racecar had even been built

could withstand the loadings but it also had a direct impact on the racecar's aerodynamic performance 'You are always looking for that extra space, because, for example, a smaller wishbone cross section is more desirable,' Toro Rosso's head of aerodynamics, Brendan Gilhome, says. 'With the regulations set quite late it took a long time to understand the implications of everything and this had a knock on effect on the development of the car.'

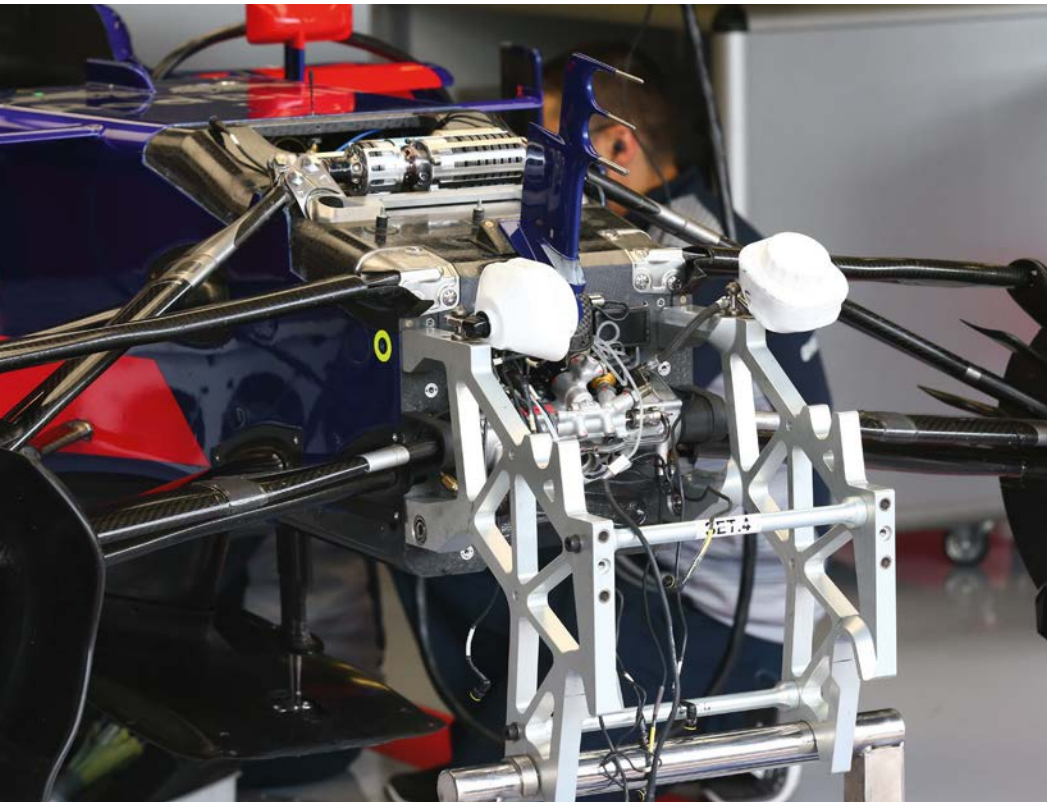
However, while this might have seen some organisations lean toward a conservative design, Toro Rosso actually adopted an extreme design solution on its front suspension. Looking at the car at a superficial level, the layout actually seems conventional, with pushrod actuated front suspension and pullrod at the rear. The front torsion bars are mounted in the top of the monocoque a little way rear of the front bulkhead, again not an unusual layout.

But the upper front wishbone mounting on the STR12 is unconventional, the wishbone actually ends slightly short of the upright and an extension extends outward and rearward to meet it. It is rather reminiscent of the Lotus 49 layout, something first spotted by Red Bull's Adrian Newey during winter testing. This layout is thought to be used for aerodynamic reasons – it is also another feature which the Toro Rosso shares with the Mercedes.

'It is a design we actually looked at for the 2016 car but at the time it did not give us high enough returns and it has some notable mechanical challenges, as you might imagine,' Key says. 'But we had time to look at it properly for the 2017 car and found it worked a bit better than a conventional solution. The biggest challenge, as you might also imagine, is really the structural integrity of it all. When you think about it there is this sort of cantilever holding the top wishbone on. In a cornering condition that component is in tension on the outside wheel. After enough analysis it can be made to work though, but it is not easy.'



Front suspension members had to be significantly stronger than in 2016, resulting in a larger cross section



Front bulkhead: note the third element and the metal inserts at the inboard suspension mounts. Beyond the trick wishbone attachments the suspension treatment is conventional with torsion bar springs – pushrod actuated at front, pullrod at rear

Detail design

Key adds: 'Mercedes went a bit further in that. They have single shear on their bolt so it's sat on top of the bracket. We played it a bit safer by going just inside the bracket and going double shear. There are lots and lots of details in there which are pretty tricky to get right. From an aero point of view it is good, but it may not suit every car. It is very dependent on everything around it, like the nose shape, the front wing, brake ducts, what happens downstream. Mechanically you can tune it to get what you want pretty much. It's not as big a deal as it looks. Your kingpin axis is a bit different, a bit further inboard at the top, but it's not actually that far off something normal. Kinematically it's not a big deal either. Actually it opens up a few options which you might not be able to do otherwise. Compliance wise it was a challenge in terms of getting the spacing of the wishbones right, but it all turned out okay after some hard work.'

Shift work

Another component which has a very long lead time where work had to begin before the loadings were really understood was the transmission. Toro Rosso has a long history of designing and manufacturing its own transmission casings, rather than utilising those built by another team. The STR12 is fitted with a composite casing with the internals produced by Xtrac, with some of those internal parts shared with the Red Bull RB13.

'There is still a big advantage to making your own gearbox; it means you have complete freedom in terms of the transmission casing and inboard suspension,' Key says. 'This is important, firstly for aerodynamics, a listed part of the car so it cannot be shared [you can't buy in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Toro Rosso adopted an extreme design solution on its front suspension

Roll hoop showing the segments in air intake. The central part is for combustion air to the Renault V6 while the side sections are for cooling. Toro Rosso introduced centreline cooling to Formula 1 in 2014

Nose is very similar in concept to the Mercedes, though STR12 uses an array of NACA ducts on the underside while the W08 uses a large scoop

TECH SPEC

Toro Rosso STR12

Chassis material: Composite monocoque structure

Power unit: Renault RE17 (badged as Toro Rosso)

Suspension: Upper and lower carbon wishbones; torsion bar springs (pushrod actuated front, pullrod rear); anti roll bars.

Steering: In-house built power-assisted rack

Transmission: In-house single piece composite casing; 8-speed sequential (with reverse) hydraulically operated.

Exhaust: Inconel in-house design

Brakes: Carbon/carbon with Brembo calipers; in-house brake by wire system.

Extinguisher system: Scuderia Toro Rosso/FEV

Tyres: Pirelli

Fuel system: ATL tank with Scuderia Toro Rosso internals

Overall weight: 728kg

from another team]. Two cars may require two different things in that area, a different set of wishbone surfaces. Our Z-bone, for example, is quite different. It's very small and complements our brake duct philosophy and diffuser. That stuff varies for every car. They all work differently, even though they are based around a similar set of principles. You need to have the freedom to make sure that is all compatible.'

Design freedom

Key adds: '[Then there] are the characteristics of your car which are largely governed by aerodynamic behaviour. Of course that will differ from car to car so you need to have a suspension which complements your aero characteristics. If you have suspension that does not allow you to run in the ranges you want to, or has some kind of incompatibility between the stiffness verse the peak rear lift that you have, then it's no good to you. If you don't make your own casing then you are not in control of that. Having that ability to tune it in is very important. Though, having said that, it does not preclude you from using another 'box. Providing that 'box and resulting rear suspension layout can be tuned in accordingly then it is okay. Force India successfully does it with a Mercedes supply, for example, and that takes a big workload off, allowing you to concentrate on other things, so there are pros and cons to it, but when you have the freedom, you use it, that is for sure.'

Ultimately, it appeared that the loads through the car were not as high as some feared, partially because Pirelli was quite conservative with its tyres, and the grip level proved to be somewhat lower than expected as a result. 'Pirelli were in the same boat as everyone else, not really understanding where the tyres would be,' Key says. 'I think knowing what we know now, we could get away with softer compounds. [But] It was right for them to be a bit cautious in case the loads going through the tyres were excessive. I have to say that while the grip is a bit low due to that conservative approach, they have done a really good job, as they had to create something without really knowing what the 2017 Formula 1 cars could do.'

More to come

Overall the STR12 has been a moderately successful chassis, a regular finisher in the points. Its most common reason for failing to finish a race is accident damage, perhaps highlighting the relative inexperience of its drivers. However, Key says that there is perhaps more to come from the car as the season goes on. 'I don't think we lack downforce compared to our direct competitors, I think we have the same or a bit better than those like Williams and Force India. Having said that, we are not at the level we would really like to be at but we are making good progress, though. Everyone wants to be closer to Mercedes and Ferrari, but I would like to be a bit closer to where Red Bull are. There is a lot of complexity to the aerodynamics of this generation of cars. If you get it right you can have a good step forwards.'

Toro Rosso looks set to continue with its innovative attempts to move forward in the pack and get closer to its sister team. And as *Racecar* closed for press following the British Grand Prix, it was on course to match its best ever Constructors' World Championship finishing position of sixth.

New blood old heart

There's been an influx of fresh technical talent at Sauber this season, but its real problem is the year-old Ferrari motor that drives its C36. Question is, is this second hand power unit actually masking the true potential of the Swiss team's 2017 car?

By SAM COLLINS

TECH SPEC

Sauber C36

Chassis: Carbon fibre monocoque

Power unit: Ferrari 061 (2016)

Suspension: Double wishbones, inboard torsion bar and damper elements (Sachs) actuated by pushrods (front), pullrods (rear)

Brakes: Calipers and pads (Brembo), discs (Carbon Industries)

Transmission: Ferrari 8-speed quick-shift carbon gearbox, longitudinally mounted, carbon fibre clutch

Chassis electronics: McLaren

ERS: Ferrari

Steering wheel: Sauber F1 Team

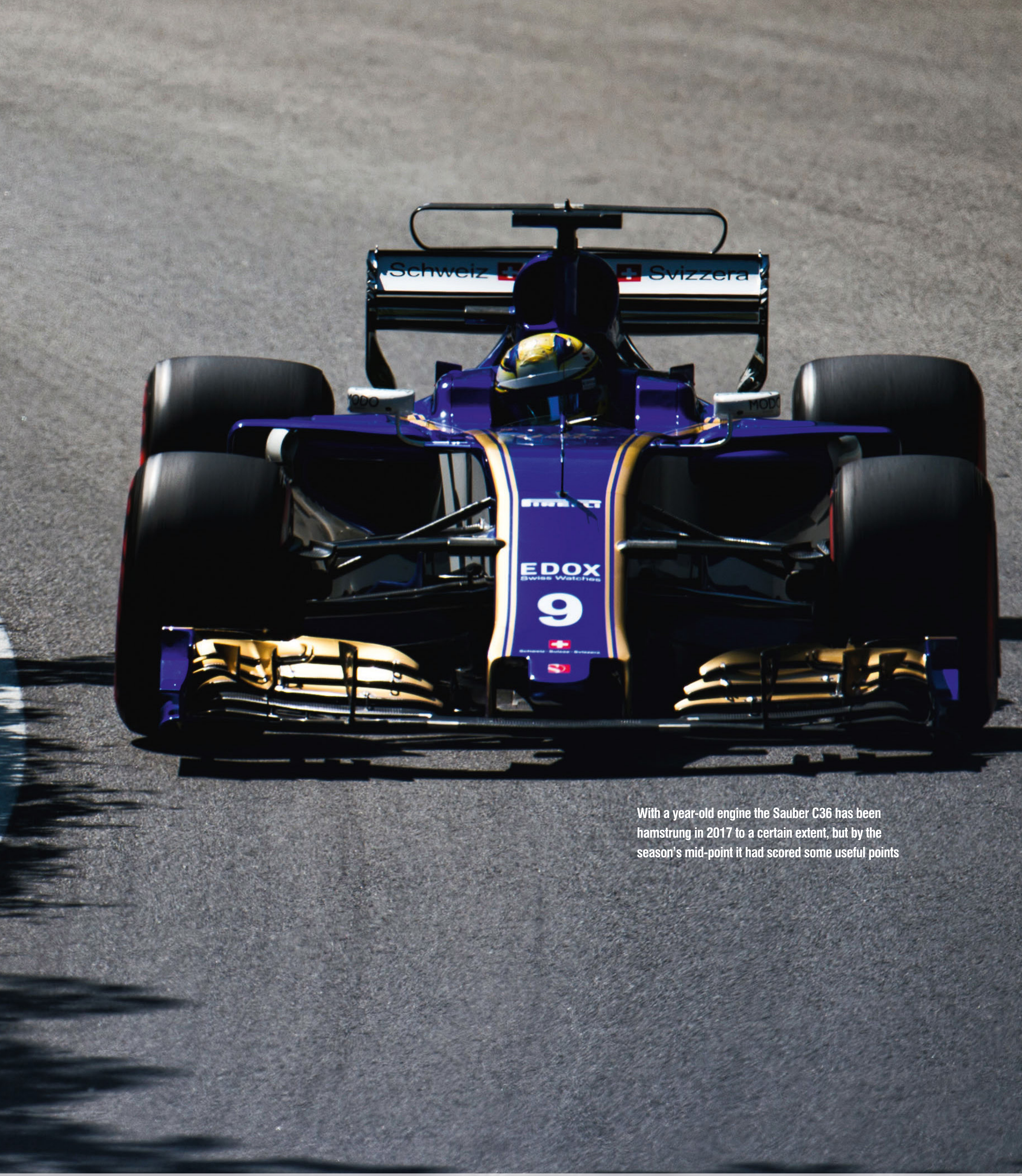
Tyres: Pirelli

Wheels: OZ

Dimensions: Length, 5143mm; width, 2000mm; height, 950mm; track width front, 1615mm; track width rear, 1530mm

Weight: 728kg (including driver, tank empty)

> 'The best thing about the C36 is that any adjustment you make, it reacts'



With a year-old engine the Sauber C36 has been hamstrung in 2017 to a certain extent, but by the season's mid-point it had scored some useful points

This year represents Sauber's 25th season in Formula 1. It's quite a landmark; indeed, only three names on the grid have a longer continuous history: Williams, McLaren and Ferrari. It is a remarkable feat for a small team from a nation where motor racing is banned.

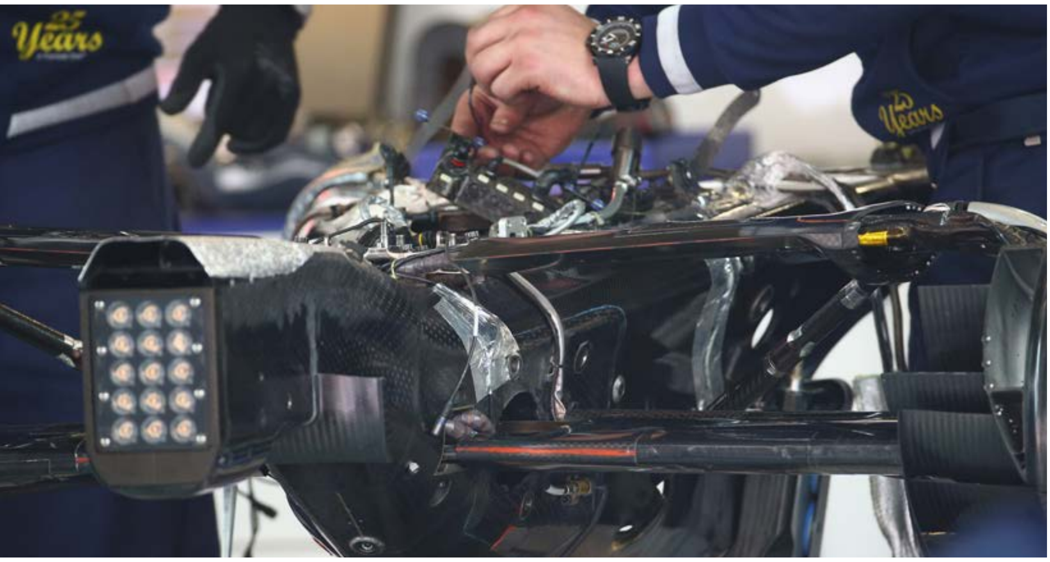
But preparation for its 25th Formula 1 season was not straightforward for the Swiss outfit. Throughout 2015 and 2016 it struggled financially, and found it difficult to retain technical staff. But the arrival of new owners and, interestingly, the withdrawal of Audi from the World Endurance Championship, has given the team an opportunity for a resurgence.

A few days after it was announced that Audi would not race its R18 LMP1 during 2017 Sauber announced that its tech chief Jorg Zander would join Sauber as its new technical director. 'I started in January, so by the time I started I couldn't really do anything in terms of the car. The first car was basically being built. All the long lead time parts had been decided and were being manufactured,' Zander explains.

'One of the first things I wanted to do was to look over the car, find out what had been designed and to get a bit of an up to date

'I needed to find out where we lacked capacity, resource and expertise in this team, so that was the biggest priority'

C36 packs the 2016 Ferrari power unit. Many have been surprised that this PU has been capable of withstanding 2017 loads



The C36 also uses the 2016 Ferrari transmission, though in this case modifications did have to be made to cope with loads

understanding of Formula 1,' Zander adds. 'I had been involved in WEC for the last six years, as the technical head of the Audi programme in 2015 and 2016. I had to re-adapt back to Formula 1. More important, though, was to understand the organisation of the team. Work out who does what, look at the configuration of the various departments and what the working practices are. I needed to find out where we lacked capacity, resource and expertise, so that was the biggest priority.'

Team building

What Zander found was a team still dealing with the after effects of the financial turmoil of recent years, and he immediately set about trying to improve the situation. 'This team suffered from a difficult financial situation, so there were various more experienced and specialised staff leaving and returning to England,' he says. 'So that puts an extra strain on things and means that you lose the flexibility to make late changes to the car. In the first six weeks I was at the team we identified some weaknesses, and as a result we made some appointments I was really happy with, like Ian Wright from Pratt and Miller. I knew him from the team in Brackley [BAR/Honda/Brawn] when we were both there. He is very strong in the vehicle performance sciences and that was an area where we were not very strong. Then we put more people into this area and it's something we are still developing at the moment.'

Changing heads

It is clear that the restructuring and rebuilding of Sauber is still a work in progress. Indeed, shortly before the F1 summer break the team appointed a new team principal, Frederic Vasseur, to replace the departing Monisha Kaltenborn (see page 94), just one in a long line of new hires. 'We have new heads of aero, track engineering and systems and, of course, I'm still new too,' Zander says. 'It takes time to adapt, people need to learn the best ways to communicate with each other. We are all experts in some field and discussing the same project there are different ways of doing things and you have to find ways to work in harmony, it's a very difficult task. We are also still recruiting, and for those who come from other teams there can be a delay as there is a regulation that they have to be off for six months first. That takes time and then you have to integrate them into the team and that takes at least three months, so there is still a lot to do.'

It is clear, however, that Zander and indeed the whole team feel optimistic about the future, but is also under no illusion that the change will not take place overnight. 'We have a lot of ability in this team, and the owners [Longbow Finance]

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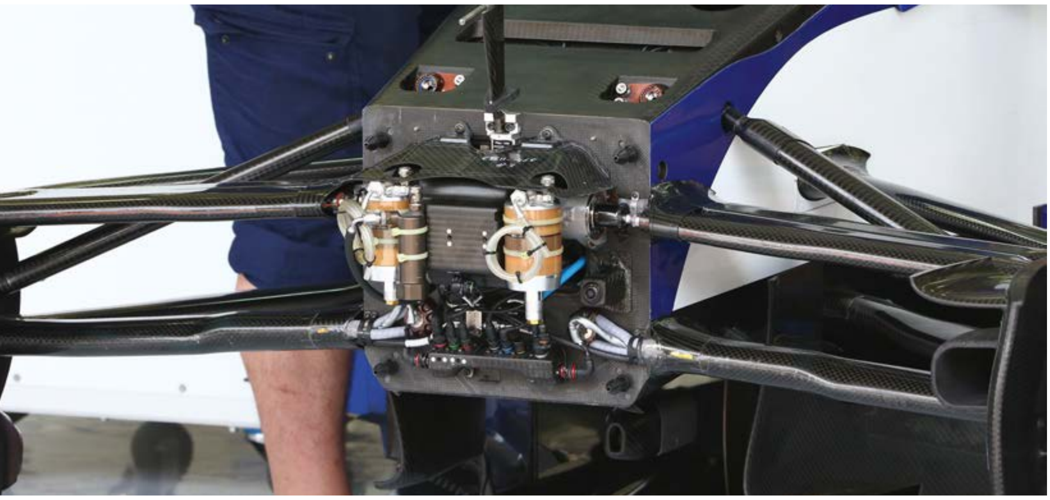
'You need to understand the trade off between weight and stiffness'

Front brake. Stopping is courtesy of Brembo carbon pads and Carbon Industries discs. Brembo also supplies the calipers



C36 uses inboard torsion bars, and dampers from Sachs, with the popular pushrod front and pullrod rear suspension layout

Higher 2017 loads mean beefier wishbones. Making sure the tyres are in the right operating window has been a challenge

are lovely people and very supportive. But a big bag of money alone is no solution,' he says. 'Getting the most out of the resources, including human resources, takes time and effort. People need to enjoy what they do, so you have to minimise the grief and kill off any politics as much as you can. You need to make sure people are happy to get the best contribution from them. You have to install working practices to ensure good levels of information exchange and understanding. Then you need to have a decision making process in place which gives the whole team a clear path.

'But what takes time in a team of 200 people are the different characters, different reactions and different habits to deal with,' Zander adds. 'There may be an established process of doing things, but there may also be better, more efficient, ways too, and that is important in a team with limited resources. My experience tells me you need to have a very efficient team, one that understands teamwork and collaboration. It is not like the old days where one person calls the shots and makes all the key decisions. I like to work in a more democratic way. A Formula 1 car is a highly complex machine and it requires different experts in different areas, they all need to link up and collaborate. You can't just put a structure on a piece of paper, click your fingers and expect it to be implemented.'

Engine stress

Once Zander had initiated the restructure of the technical department his attention turned to the team's 2017 car, the Sauber C36. It is a fairly conventional car by 2017 standards, but uniquely it is powered by a 2016 engine, the Ferrari 061. This is something which many in the paddock find surprising as the 061 was designed to be a fully stressed member in the 2016 Ferrari, but not for a 2017 car with its much higher loading. When asked what would happen if a 2016 specification V6 was fitted to a 2017 car Renault's Remi Taffin was unequivocal at the start of the season; 'it would break,' he said. However, the Ferrari engine in the C36 has not broken, leading some to speculate that it may have been rather over-engineered.

'It's a substantial increase in terms of torsional loading, you can't ignore it,' Zander says. 'There are higher loadings through the block, so perhaps this Ferrari engine is a bit stronger than other engines. We really have not had any issues with it. In terms of pure vehicle dynamics the torsional stiffness this car has got is acceptable, it is really not bad. We had cars with about 9000Nm per degree axle to axle, and we had some with 12 to 13,000Nm per degree. If you go into the world of touring cars and sportscars it is even higher with 30,000Nm per degree. It is a number you want to improve

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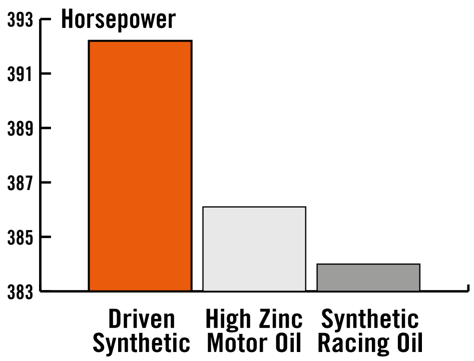

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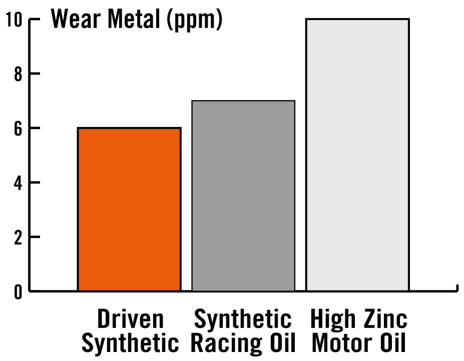

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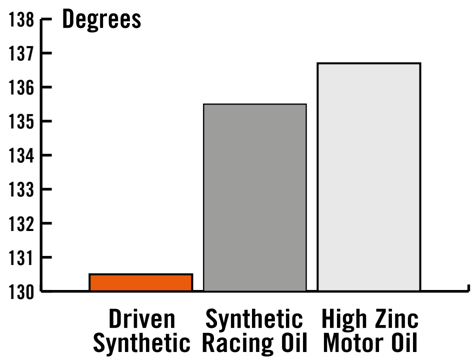

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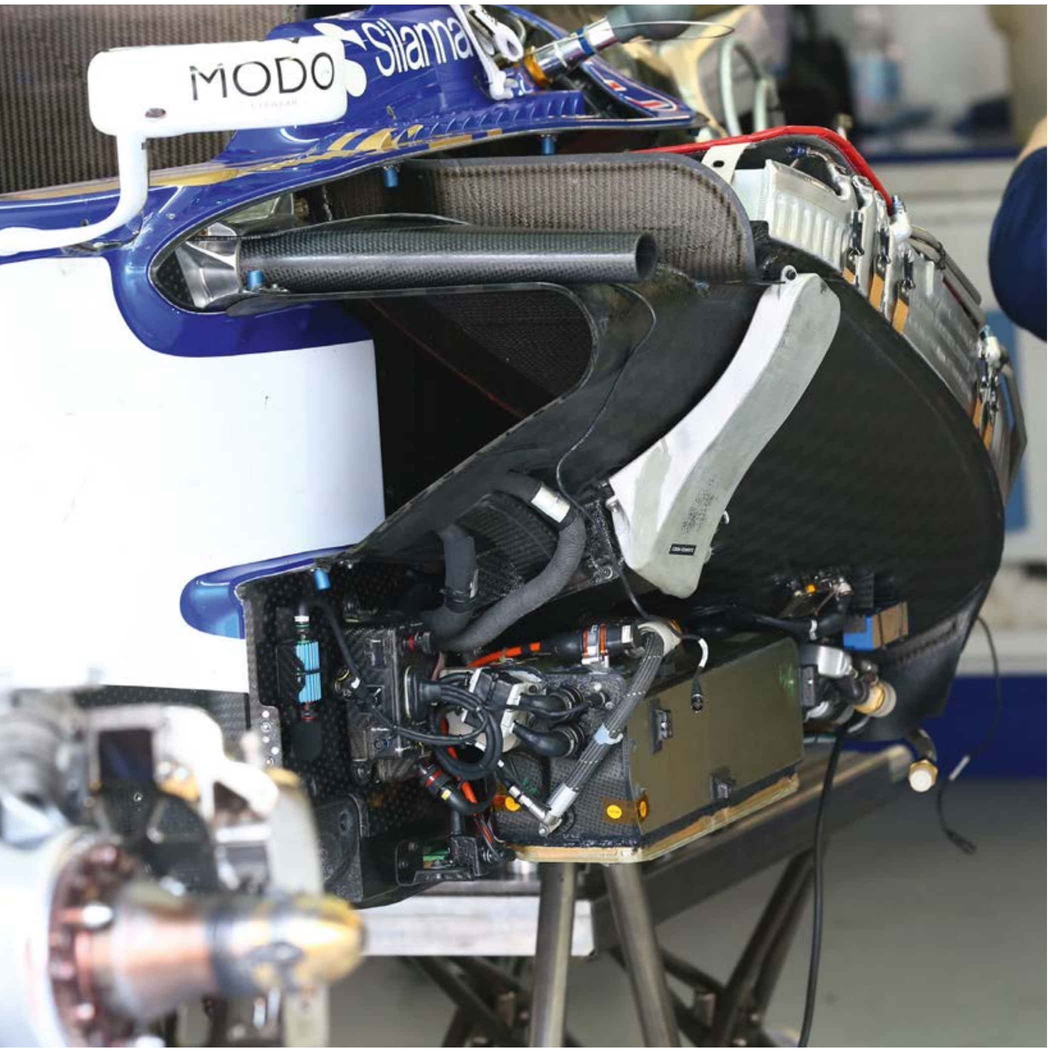
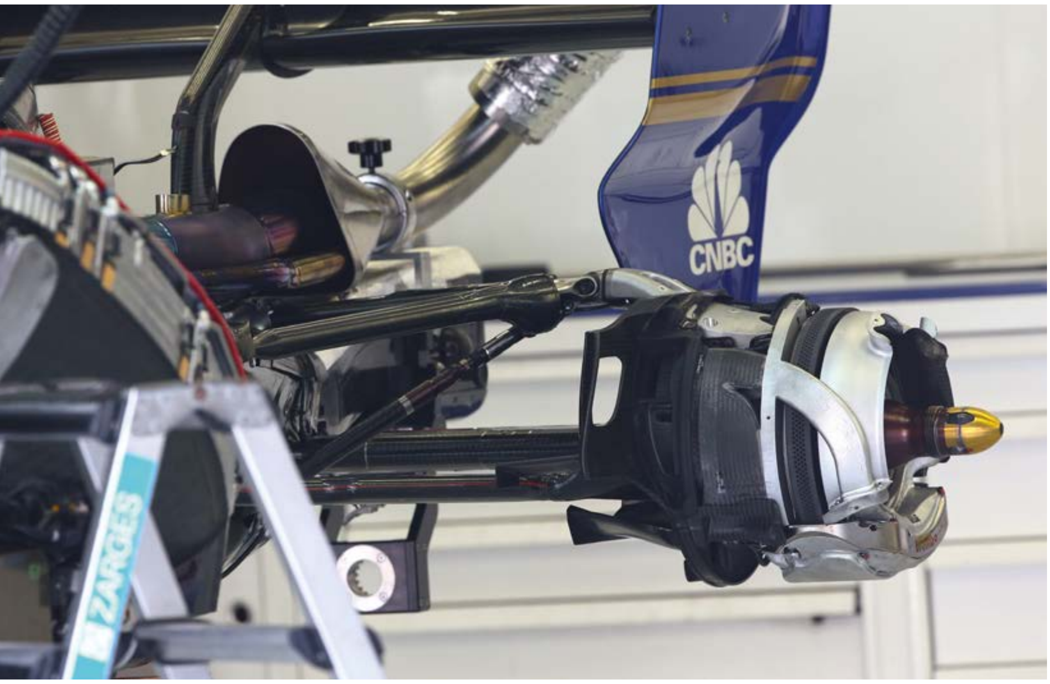
'The more you can control the platform of the car the better efficiency you can get from aero performance'



Minimising sidepod volume was a key aim on the C36 and Sauber says it will continue with this approach with the 2018 C37



Rear suspension. Sauber was considering an 'active' approach to the suspension but held back after FIA rules clarification

always for a given amount of weight. You need to understand the trade-off between the weight and the stiffness. In terms of kinematics and compliance there is still a high level of controllability with local stiffness arrangements; with springs and damping systems.'

The C36 also utilises the 2016 Ferrari transmission rather than a full 2017 version, but unlike the Italian V6 the composite casing did need to be strengthened in order to cope with the higher loads. 'The main case had to be modified for structural reasons, it would not have been strong enough otherwise. Using the Ferrari gearbox we are limited on the inboard suspension layout, but the kinematics are not bad. We have some possibilities there in terms of changing the roll centres and camber change. The rear of the car does what it is supposed to do, it's quite stiff so I don't think we are losing out too much there,' Zander says.

Regulation issue

One of the first things Zander had to deal with in terms of the C36 when he started at Sauber was a ban on suspension systems designed to make the rear of the car pop up at low speed and squat down at high speed. Something which gives an aerodynamic benefit.

'We were considering that direction, I was very interested in it actually, but it was not a big deal for us when the clarification came,' Zander says. 'I think Charlie [Whiting] wanted to make sure the aerodynamics were not developed in such a way to be reliant on such things. As far as I see there are types of corners where you would want to have more rake on the car, hence there are cars running quite a lot of rake, but there are other situations on the same lap where you don't want so much rake on the car. You want to reduce the drag level and in turn downforce as it is not needed. Everyone sets an aero target which is desensitised to platform movement in terms of pitch, yaw, steering angle. Everyone is doing it, but on the other hand the more you can control the platform the better efficiency you can get from aero performance. It is a big contribution to the overall downforce level.'

Interdependence day

Despite the ban Zander believes that there is still scope for development in this area, working within what is allowed by the clarification issued at the start of the season. 'There may be different ways of looking at it. If you have a pure hydraulic system where you introduce characteristics which are introduced by switching from one level to another, that is one way of doing it, or having hydraulics and pneumatics is a more complex way. Then there is interdependency in

‘With limited resources you can only do so much with the racecar, but we do have a lot of updates planned’

terms of roll and heave so that is one way, too. I think there is nothing that prevents anyone from introducing either digressive or progressive spring rates, that is still something that could be done. There are still a lot of things that can be done with conventional suspension and I think there are people doing exactly that. We have an interest in that too, of course. There is a fine line.’

Audi windfall

The aero development of the C36 was disrupted as the Sauber wind tunnel was booked out for most of 2015 and 2016, ironically by Zander who was at the time developing the Audi R18 LMP1. ‘While there is no R18 project at the moment we still have customers using the wind tunnel, but there is not as much of a limitation on the F1 project now as there was. But we still have limited resources, so we have to ensure we maximise output,’ Zander says.

With more wind tunnel time available and a stable rulebook for 2018, the Sauber engineers are now hard at work developing the aerodynamic package of the C36. ‘We lack up to 30 points of downforce so we are trying to catch up,’ Zander says. ‘With limited resources you can only do so much, but we have a lot of updates planned. We will improve the cooling a bit, which will improve not just cooling but also performance in the second half of the season. Our so-called Barcelona upgrade, which actually appeared at Monaco, a lot of people said that it didn’t work. It did work, it’s just that in Monaco we just screwed up. We tried to be really clever with the chassis set-up but this just didn’t work in the way we expected it to. We used a bit of experience and a bit of a textbook approach, but with those tyres it just didn’t work.’

Indeed, getting the most out of the tyres seems to be the dominant factor in Formula 1 in 2017 and to a greater extent than many may realise. ‘What you have to do this season is to move away from what is an ideal engineering set-up for the car and do something which just makes the tyres work,’ Zander says. ‘Making sure these tyres are in the operating window is key. You can forget about everything else to start with. The Monaco upgrade did work, it provided what we wanted it to do in terms of aero performance, but we couldn’t transfer that onto the track there. We have to make more fundamental changes to the way we set up the car compared to what the simulation is telling us at the moment because of the tyres. But we have made a good step forwards in that area and it has won some points for us.’

Decent package

Looking over the car as a whole, Zander believes that the C36 is a good basic package, but one held back by a lack of power. ‘We know we cannot conquer everyone we want to, we know the car has some built-in deficiencies, we just have to accept that,’ he says. ‘The best thing about the C36 is it works, any adjustment you make, it reacts. The team has not done a bad job at all. Recently we have worked a lot on desensitised aerodynamics, which might not have been the case right away, we are going in the right direction. There is no fundamental flaw in the concept, it just lacks downforce. If you look at the detail of the Ferrari or Mercedes you can understand the amount of detail work which has gone into those cars and that means time and resource. When we get everything together well, and all elements delivering the maximum, then the car is not at all bad, the drivers are happy with it. But you have to accept that is the limit of the performance.’

In 2018 the Sauber team will change power unit supplier, though before the summer break there was some uncertainty about this and there were reports that a deal with Honda had not only been cancelled, but rather it had not been fully agreed in the first place.

The Honda deal might have meant more financial latitude for Sauber, but it seems the recent lack of performance of the Honda in the McLaren has scared the team off. Zander does not seem too concerned over losing a possible works power unit deal, though. ‘I am optimistic for the C37 [2018 car], and for the future, we have set some really good targets, I know we can do this, we have really good talent here, good engineers, good people and a lot of really interesting ideas,’ he says.

‘C37 will be an evolution of the C36 concept,’ Zander adds. ‘But with a more powerful engine we will be able to show what the potential really is. At the moment the sad thing is we cannot show that potential. I have advised the team to be much more radical in some areas, so there will be much more innovation in the car.’

Swiss roll

The C36 features a distinctive roll over structure, featuring a singular perpendicular blade of the type used by Force India, Caterham and Mercedes some years back. Ducts feeding air to coolers in the centre of the car, and the V6 air for combustion, are located either side of the structure.

‘There was a significant weight saving by doing it that way,’ Zander says. ‘I’m not sure we will use it next year, however. It does have some impact on the airflow into the apertures up there when the car is in yaw. It’s not too big an impact on the engine but it does effect the cooling efficiency. That is just another compromise to deal with.

‘A more circular entry does make it easier to control the attacking flow rates, so we are looking into that,’ Zander adds. ‘I think the centreline cooling concept is a clear advantage. We want to try to minimise packaging in the sidepod area and package more and more in an area which is less aerodynamically sensitive. I think everyone will go that way.’

A single upright blade helps divide the air through ducts that feed in to the Ferrari V6 ICE and to the Sauber C36 coolers

Brute force

They're big and brash and should make for spectacular racing, but can the new diesel-engined SuperUtes really replace the V8 trucks in the hearts of Aussie race goers?

By STEFAN BARTHOLOMAEUS

The death of Australian automotive manufacturing and its home-grown Ford Falcon and Holden Commodore has presented major challenges for organisers of the Supercars Championship. It is evolving to welcome V6 turbo engines and, possibly, two-door body shapes as well. But while that marks a significant technical challenge for the category and an adjustment for a fan base brought up with its beloved V8 sedans, the evolution doesn't stop there.

One of Supercars' key support acts is the V8 Utes Racing Series which, running since 2001, played on the Ford *vs* Holden rivalry by featuring production Falcon and Commodore-based utes. While iconic in Australia, the car-based utes ('ute' is short for utility and is the Australian term for a pickup) have been overrun across the last decade in the road car market by imported SUV-based trucks. The SUV-based utes now represent almost 20 per cent of the new vehicle market, with the Toyota Hilux and Ford Ranger among Australia's highest selling individual models. So, although not natural racecars at first glance, when it came to future-proofing the Ute series, the direction seemed obvious.

Thunder's truck

Supercars took over the V8 Ute Series after the previous management, in which the competitors were the shareholders, fell into financial stress at the end of 2015. Plans had been announced earlier that year for a new-generation Ute platform featuring a purpose-built control chassis, to be fitted with various SUV-based bodies and V8 engines. But this was expensive and lacked manufacturer support and failed to get off the ground, so Supercars has now headed for a low-cost, very much production-based, formula to move forward.

Led by its sporting and technical director David Stuart, Supercars has now developed a 'racing kit' – which will retail at $60,000 AUD (£37,000) – that competitors can fit to a production vehicle and go racing.

Supercars and fabrication specialist Pace Innovations combined to design a control rollcage and rear-axle housing as part of the package, with safety, low cost and parity the key cornerstones. Pace is run by former Schnitzer Motorsport engineer Paul Ceprnich.

Supercars has now homologated six vehicles – the Toyota Hilux, Ford Ranger, Mitsubishi Triton, Mazda BT-50, Isuzu D-Max and Holden

The Ford Ranger is one of six dual-cab trucks to have been homologated for the new-for-2018 SuperUtes series. They will be diesel powered

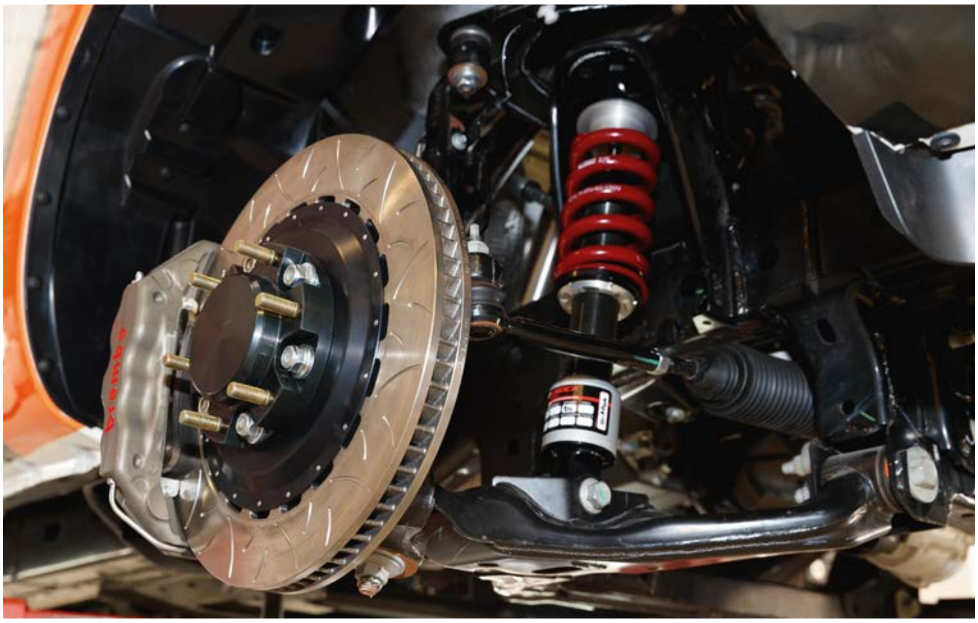
Colorado. All six will race in their dual-cab, diesel engine configurations, which represent the most popular examples within the booming segment. The SuperUtes series was scheduled to kick-off midway through this year before being pushed out to 2018 in order to give more time for the final specification to be locked down and tested.

Pickup pieces

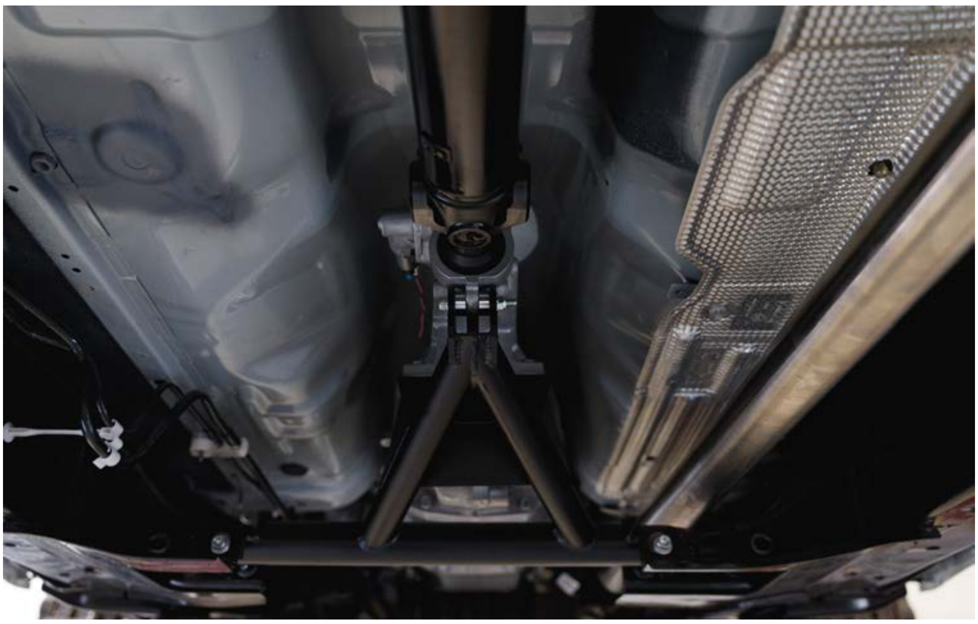
'The first step for us was to do a desktop audit on what models would be suitable for the vision that we had for SuperUtes,' Stuart says. 'We looked at all the engine specifications as standard and then went about how we could produce a production-based vehicle with a heavy emphasis on safety and also containing the costs of the build of the vehicle with as many common components as possible.

'We then sourced one vehicle from each of the six manufacturers and undertook an internal cockpit scan, an engine bay scan and an under-vehicle scan of each so that we could compare the dimensions for rollcage, rear-axle assembly, bell-housing modification, gearbox location and the like,' Stuart adds. 'We wanted to have a common rear-axle ratio for parity purposes. Looking at each manufacturer we weren't going

Supercars series preparation specialist Pace Innovation has designed and produced a spec rear axle housing as part of the SuperUtes package. It incorporates the damper mounts and the rear anti-rollbar while the mounting is common as well



Part of the spec kit for the Utes is a heavy-duty Brembo brake package (six-piston front and four-piston rear) and Tilton 600 Series pedal box. Damping is by Australian company Supashock and its products work in conjunction with Eibach springs



One of the first tasks was to scan the underbody of all the vehicles to find out just how much work would be involved in making the trucks equal. The control parts include a Tremac T56 gearbox which carries over from the current V8 ute

SUV-based Utes now represent 20 per cent of the new vehicle market

to be able to achieve that without having the one gearbox common across all vehicles and one axle housing. We looked at various things like track and wheel base to assist in the design of the housing and look at how it was going to be packaged in each vehicle. The bespoke housing that Pace designed incorporates the damper mounts and the rear anti-rollbar and the mounting is common as well. Trying to land damper mounts off the standard chassis across each of the vehicle types was going to give us different motion ratios across each vehicle. This way the motion ratio of the rear suspension is the same across each one.

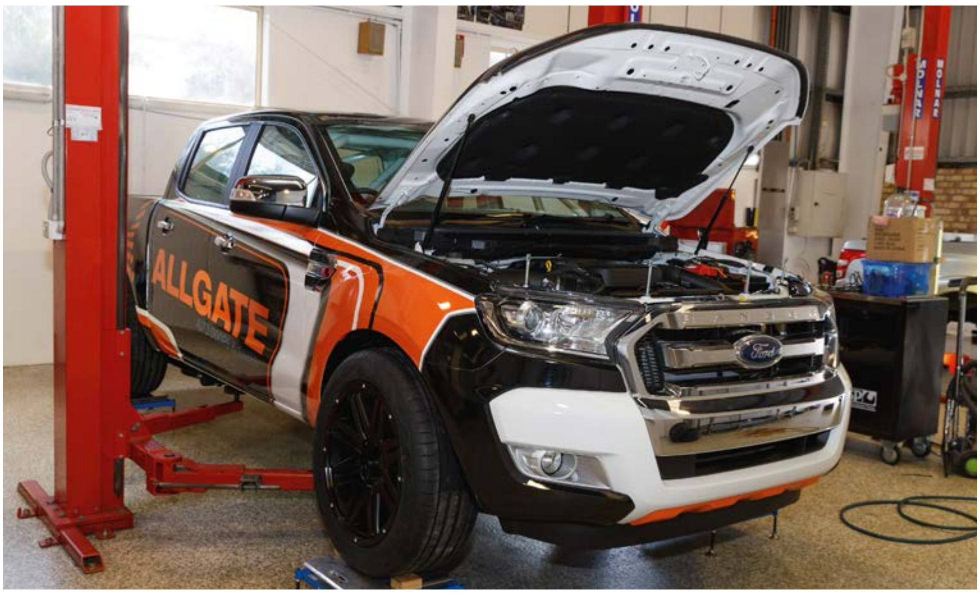
'The final packaging looks quite unique,' Stuart says. 'But from a design concept it was the most efficient way of fitting the vehicles and providing some adjustability from ride height and the rest of it as well. Essentially it's a sporting parity rule, so spring rates, ride heights and anti-rollbar rates – particularly in the rear – across the vehicles we'll be able to alter which will assist us with the lap time parity.' In addition to the cage and axle housing, the racing kit features a Tremac T56 gearbox that carries over from the current V8 Utes, which is mated to a 230mm twin-plate clutch by Extreme, which also supplies the control flywheel.

'That part of the driveline is a known quantity for us, but the challenge has been in the bellhousing,' Stuart adds. 'With quite a few of the vehicles we've been able to use a standard bellhousing with an adapter plate fitted, but there are two – the Ford and Mazda – that required a bespoke housing to be produced.'

Truck stop

The racing kit also includes a heavy-duty Brembo brake package (six-piston front and four-piston rear) and Tilton 600 Series pedal box. 'The feedback from the current V8 Ute competitors was that they'd like better brakes and a pedal box with adjustable front-to-rear brake bias, which we've incorporated into the floor-mounted pedal box,' Stuart says. 'The Brembo brakes are a known quantity. The front rotor [disc] size is almost identical to that on the Supercars. With this style of vehicle all your attacking will be done into the corner, so we expect this will aid the racing on track.'

The rollcage is a standard component and stretches back in to the dual-cab space. The full parts kit will cost $60,000 AUD



Parity of the diesel engines will be ensured with measures already used in Supercars series, coupled with weight reductions

High rider

The kit also includes dampers by Australian brand Supashock, coupled with Eibach springs. Unlike the rear, the front-suspension retains the production architecture, with the control shock, spring and a mounting system for the Brembos the only changes.

Even in race trim, the ride height of the vehicles remains considerable, with 80mm retained between the top of the wheel and the inner guard. The wheels are 20 inches in diameter wrapped in a 265/50 high-performance street tyre, with several brands to be tested before a final supplier is locked in. 'We may be able to reduce the right height a little bit but you've got to remember that these cars won't be as stiffly sprung as a Supercar so you need a reasonable amount of travel for when they hit a kerb or drop a wheel off the circuit,' Stuart says.

Whether the wheel arches themselves need to be modified is also being assessed. The desire for a standard track width means that the wheels protrude by around 20mm on some vehicles, potentially creating a hazard in door-to-door combat. But that issue may be somewhat self-correcting with Supercars informing competitors that they can fit commercially available bodywork from aftermarket vendors catering for the dual-cab ute road market.

Diesel genes

As for the engines, a Motec dash and ECU adapter come as part of the control kit, with the Australian company working closely alongside Supercars on an engine programme that requires widely different engine configurations to be balanced.

Meanwhile, Supercars will utilise its existing Accumulated Engine Power (AEP) and Engine Power Weighted Average (EPWA) formulas developed for its main championship as part of the SuperUtes parity system. The former consists of the summation of power outputs at 50rpm increments over a designated working rpm range, while the latter factors in the time spent at each of those rpm sites based on data collected from various circuits.

Where the SuperUtes engine parity will differ to that traditionally used by Supercars, however, is that engines from each manufacturer will have their own horsepower targets that will be balanced against different minimum

‘The engine programme for this series is a massive undertaking because you’ve got varying capacities and configurations’

weights. Stuart quotes 340bhp and a hefty 500ft.lbs as the general performance targets, but reducing the minimum weight for vehicles unable to easily match those figures has been deemed a cost-effective way of evening the playing field. ‘The engine programme is a massive undertaking because you’ve got varying capacities and configurations,’ Stuart says. ‘Everything from a two-point-something four-cylinder to a three-point-something V6, if someone wants to race a VW Amarok, to the 5-cylinder Ford Ranger.

‘We actually had to change our approach to how we were going to conduct the parity and the testing, as we’ve built the vehicles and learnt more about the weights we can achieve,’ Stuart adds. ‘We talked about having 1850kg as a minimum weight, but we can actually build the cars lighter than that. We will still have the AEP and the EPWA as a known for each engine and we’ll be able to use that in conjunction with the weight of the vehicle to come up with a suitable power per kilo value for each vehicle. That will assist us in creating some lap time equality from the vehicle with the smallest capacity engine to the vehicle with the largest.

‘Once we’ve encapsulated the range of power we’ll optimise each engine and then it’ll be sealed. As a new competitor you’ll come in, send the engine to the Supercars dyno facility, it’ll be tuned and optimised and then sealed,’ Stuart says. ‘What goes racing will be very, very similar to the production engine. The only thing we’ll look to be changing might be the turbocharger, but we’ve got to put miles on that and see what the durability is like.

‘Obviously a standard road going car is designed to do however many hundred thousand kilometres in either a quasi-family or industrial environment, but they’re not racing kilometres, so we need to ensure that you get good performance and also reliability.’

Truck on track

Then there’s the environmental factors to consider. ‘The emissions side is a critical one with this project as well,’ Stuart says. ‘We want to have good, close racing but also we don’t want to be blowing heaps of particulate into the atmosphere, so we’re working closely with Motec on controlling that side of it too.’

Dyno testing of the first engines has already commenced, while further information will be gathered once track running gets underway in August. A Ford Ranger and a Mitsubishi Triton were the first two cars to be completed in time for a public launch at Supercars’ Townsville 400 and will kick-off the testing process. This track testing will be a chance to not only evaluate the durability of components but also understand how these seemingly unlikely racing vehicles will look and perform on track.

Better than V8s?

While unlikely to impress with their outright lap speed, Stuart argues that the spectacle will be in the closeness of the racing in SuperUtes, rather than pure performance.

‘There’s been a lot of talk about how they will compare from a speed and lap time perspective to the current Utes,’ he says. ‘They are not a 5-litre V8 petrol engine, they’re a four, five or six cylinder diesel. They make their power in a different manner. I don’t see that there’s much point to comparing what the speed will be. The proof in the pudding will be whether they produce good, entertaining racing. If they’re fun to drive and if you can make good passing moves on the way into the corner then it will put on a good show.’

Ride height of these trucks is going to be huge, even in race trim there’s 80mm between top of the wheel and inner guard

Turn to Stone

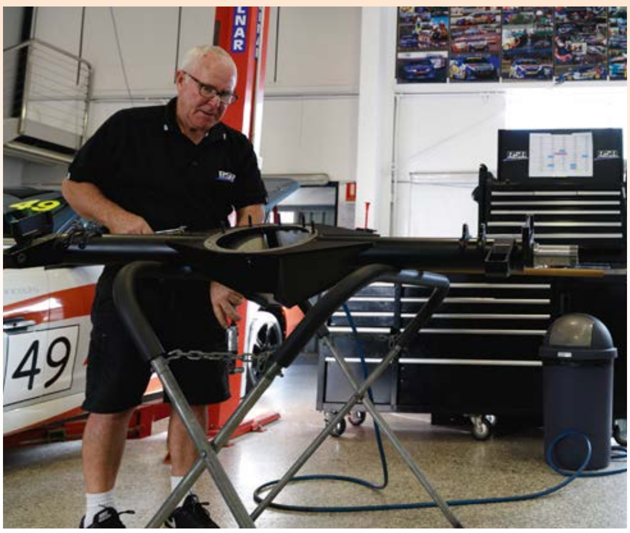
A key player in the development of the SuperUtes package has been one of Supercars’ favourite sons, Ross Stone.

The Kiwi ran Stone Brothers Racing alongside brother Jim between 1998 and 2012, winning three straight championships from 2003 to 2005 with drivers Marcos Ambrose and Russell Ingall. He was then contracted to oversee the team’s transition into Erebus Motorsport for two years after it was sold, before taking a sabbatical from the sport. A brief dabble in GT racing followed in late 2015, but it’s the advent of the SuperUtes that has caught the Supercars Hall of Famer’s attention.

Planning to run his own team, Stone threw his support behind the development process, working with Supercars’ technical team to bed the package and construct the first race vehicles.

‘We went down the road of GTs and we did those two races but I really struggled with the handicap pitstop times and all of that side of it,’ Stone says. ‘I wanted to do something else and when I started looking at the SuperUtes I saw they were going to be a good thing. The more I looked at it, the more I liked it. I’ve really enjoyed getting in and helping the Supercars technical guys put the package together. It’s been a lot of work, but once the series is up and running I’ll just be a competitor.

Stone also welcomes the much talked about change in the engine philosophy. ‘I think it’s a good challenge getting involved with diesels and everything that goes with that,’ he says. ‘One of the plusses is that Motec worldwide want to become more involved with diesel electronics and they have been a big help. That’s made the whole thing a bit easier.’



Supercars legend Ross Stone has played a big part in SuperUte development

Alfa bravo

From the outside it looks beautifully basic, but under the skin there was enough engineering ingenuity to humble the Silver Arrows in their own backyard. Here's the full story of Alfa Romeo's wonderful P3

By WOUTER MELISSEN

There were around 250,000 spectators gathered for the 1935 German Grand Prix at the Nurburgring. Among them were many high ranking officials of the Nazi government. At that time grand prix racing was still very much a nationalistic affair, with manufacturers representing their countries. A Silver Arrow victory seemed almost inevitable, with the government-backed Auto Union and Mercedes-Benz teams the clear favourites.

Yet to the great embarrassment of the officials in attendance, Tazio Nuvolari and his four-year old, Scuderia Ferrari-entered Alfa Romeo, had other ideas. He produced one of the

The P3 is an engineering work of art that is very much a complete package

Tazio Nuvolari leads Rene Dreyfus in the 1935 Pau Grand Prix, both at the wheel of Alfa Romeo Tipo Bs (more commonly known as P3s). In the same year Nuvolari scored the car's most famous victory at the Nurburgring, where it defeated the Silver Arrows

all time great drives and grabbed the 'impossible victory.' So unexpected was this outcome that the organisers did not have the Italian national anthem available for the podium ceremonies. Fortunately, the 'Flying Mantuan' was much better prepared and had brought his own copy.

Alfa male

Although unlikely, the outcome of the 1935 German Grand Prix was by no means a fluke. Nuvolari was one of the greatest grand prix drivers and was revered by his contemporaries. In fact, Auto Union works driver and compatriot Achille Varzi had vetoed Nuvolari from joining the German team at the start of the 1935 season. His plans to jump ship had disgruntled Nuvolari's former team manager Enzo Ferrari and he was initially not allowed to rejoin Scuderia Ferrari for the new season. This was the de facto Alfa Romeo works effort, and Italy's best hopes of success in the major grands prix.

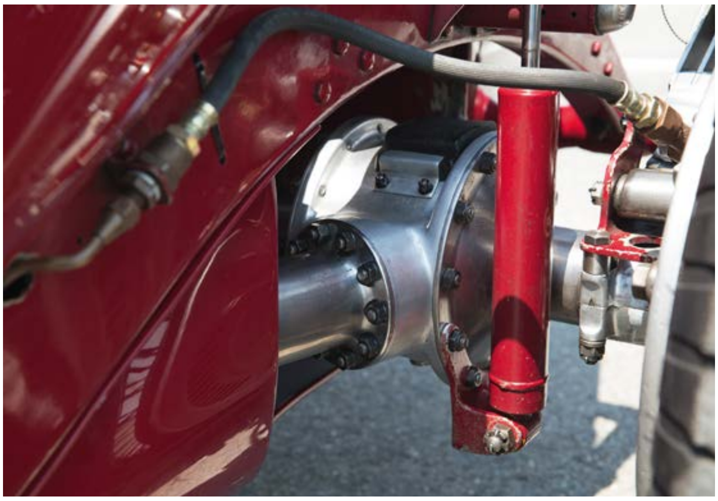
Like the German government, Benito Mussolini's administration also recognised the publicity value of motor racing success and he personally urged Enzo Ferrari to hire Nuvolari, as this was in Italy's national interest. Along with Nuvolari and Ferrari, the third major person responsible for Alfa Romeo's success was the hugely talented designer Vittorio Jano. He had been lured away from Fiat by Ferrari during the early 1920s and had created a range of hugely successful road and racing cars for Alfa Romeo since then. But the 1935 German Grand Prix winner, the very car pictured in this feature, is certainly one of his very finest creations.

Truly Jano's

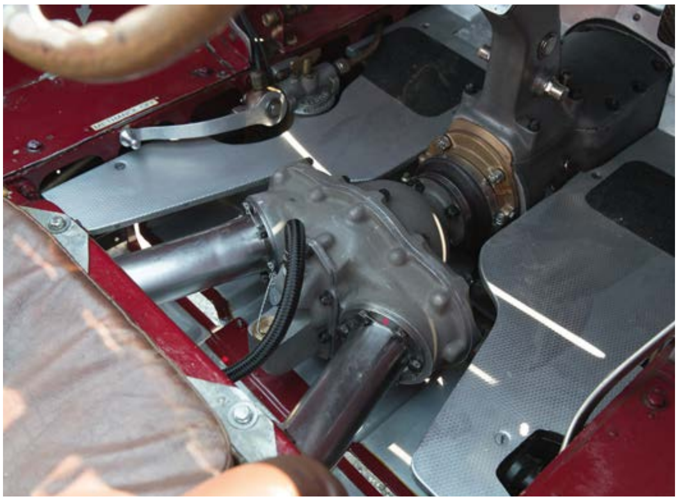
Originally simply referred to as the Monoposto, the new-for-1932 Alfa Romeo grand prix car replaced a pair of distinctly different machines introduced a year earlier. The best known of these was the grand prix version of the versatile

Dubonnet type front suspension consists of a rigid mounted beam axle with short trailing arms connected to the axle through kingpins, plus internally mounted spring and damper

At the rear quarter-elliptic leaf springs were fitted by Ferrari and one of the friction dampers was substituted with a hydraulic shock. The drum brakes are also hydraulic



Rear suspension showing the end of one of the bifurcated drive propshafts. This unusual system offered a weight advantage in that the P3 didn't have to carry a heavy live rear axle



The 4-speed 'box sits between the legs of the driver with the stick protruding from it. The differential is bolted directly to the gearbox and is also situated in the P3's cockpit

8C 2300 that following its debut success at Monza was dubbed accordingly. Not designed as a grand prix car from the ground up, the Monza was part of the 8C 2300 family that was available to customers and in various guises would go on to dominate sportscar racing for many years. Among the eight-cylinder engined machine's many achievements were four consecutive Le Mans 24 Hours wins between 1931 and 1934.

Alongside the 8C 2300 Monza, Alfa Romeo also ran the purpose-built Tipo A during the 1931 season. One of Jano's more elaborate designs, it featured a pair of straight-six engines mounted side-by-side ahead of the driver. The complicated system also included a pair of gearboxes, with separate propshafts powering one rear wheel each.

Also dubbed the Monoposto, or single seater, the Tipo A had a centrally located driving seat. This was a first in top level competition as, although riding mechanics were no longer required, grand prix cars still had an off-set driving position, usually to the right. Both cars won races but the Monza was found to be underpowered, while the Tipo A was, not surprisingly, overly-complicated and heavy.

For his second Monoposto, Jano decided to combine what he considered the best ingredients of the two cars. Inspired by the Tipo A's twin propshafts was one of the new car's stand-out features; the bifurcated drive. This consists of a pair of propshafts connected with bevel gears to the centrally mounted differential at a 37-degree angle on one end, and to a corner of the rear axle on the other.

Twin prop flyer

Some suggested that the unusual configuration was chosen to allow the seat to be mounted lower. However, there is no significant difference in the height compared to a similar grand prix car with a conventional layout. But the bifurcated drive does offer a weight saving as it does not require a relatively heavy live rear axle. With the differential mounted directly to the gearbox, the unsprung weight the other end is also lower. One final advantage is the relatively easily accessible final drive, which does not require the rear end to be disassembled for a ratio change. The bevel gears used on both sides of the drive are more prone to wear, but this only very rarely affected the reliability.

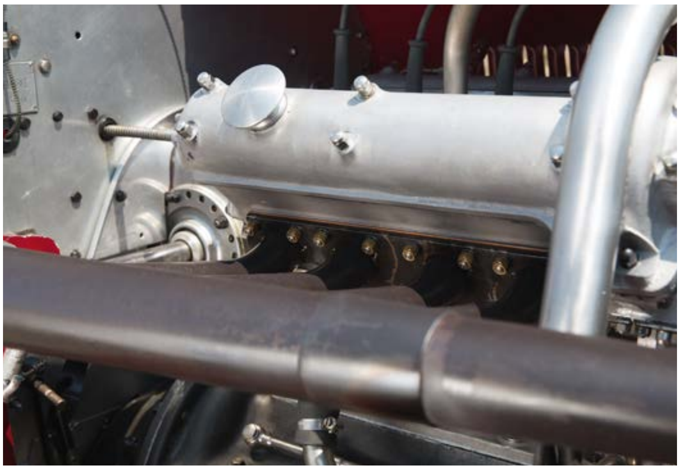
Carried over from the 8C 2300 was the lovely twin-cam, eight-cylinder engine. An engineering piece of art, it showed Jano was as much a sculptor as he was an engineer. The unit is built up of two blocks cast in lightweight aluminium alloy with integral heads. The crankshaft is also built up of two pieces and runs in 10 bearings. Sandwiched between the two halves of the engine is the gear-train that drives the twin overhead camshafts. The valves are mounted at a 100-degree angle as was the norm in the day. Interestingly, the head is perfectly symmetrical, so each 34mm port could serve as exhaust or intake. Compared to the 8C 2300, the ports were indeed switched, with the intake moved from the right to the left.

Whereas the 8C 2300 uses a large single supercharger, the grand prix car is equipped with two smaller Roots-type superchargers, each feeding four cylinders. The superchargers are mounted laterally on the intake side of the engine and are also driven by the central

It showed that Jano was as much a sculptor as he was an engineer

The aluminium body was tightly wrapped around the car's running gear. The P3 was widened to meet the new grand prix racing regulations that came into force for the 1934 season

The quite beautiful twin-cam 8-cylinder powerplant was bored out from 2.9-litre to 3.8-litre during 1935 season. It was then delivering an impressive, for the time, 330bhp at 5400rpm



The P3's engine was made up of two blocks cast in lightweight aluminium alloy with integral heads. It was rigidly-mounted longitudinally in a straightforward ladder frame

gears. Each supercharger is equipped with a Weber carburettor. Compared to the earlier 8C powerplant, the displacement was raised to 2654cc by increasing the bore from 88mm to 100mm. These revisions saw the power rise from 160bhp to 215bhp at 5600rpm.

The engine was mounted rigidly in a straightforward ladder frame, eliminating the need of additional cross-bracing at the front of the chassis. Two decades later Jano would take this principle one step further with the Lancia D50, which features a fully stressed V8 engine. Aft of the engine, three further cross-braces help increase the torsional rigidity of the frame. For the front a conventional beam axle with semi-elliptic leaf springs and friction dampers was fitted. The rear-end was similarly suspended with a pair of friction dampers on each corner. Cable-operated drum brakes were fitted on all four corners. Bolted directly to the 8-cylinder engine is a 4-speed gearbox. The lever is mounted directly on top of the gearbox and sits between the legs of the driver. The pedal operating the dry, multi-plate clutch is mounted on the left of the gearbox, while the brake and throttle pedals are both placed on the right-hand side. The 140-litre fuel tank is fitted in the tail of the car with a 20-litre oil-tank for the dry-sump lubrication system just ahead. The aluminium body is tightly wrapped around the running gear. In the original configuration, the bodywork was so narrow that the two superchargers extend beyond the engine cover.

Winning debut

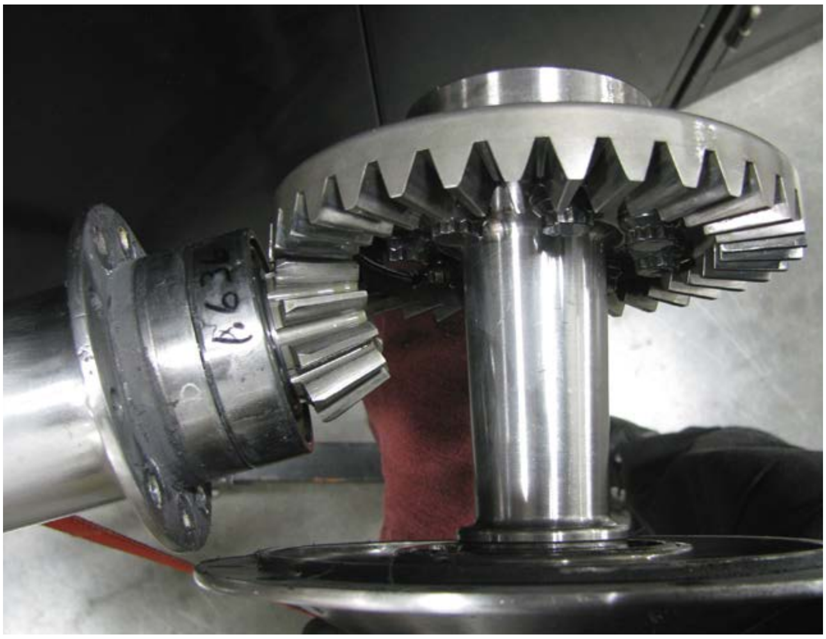
The new Monoposto was introduced at the 1932 Italian Grand Prix in June with cars entered for Nuvolari and Giuseppe Campari. At the time, a Formula Libre rulebook was in effect, which explained why Maserati could line up with a 5-litre, V16 grand prix car. Jano was well aware of this when designing the new Alfa Romeo, but instead of raw power he focused his efforts on a well balanced and above all very light racing car. He believed that quick acceleration out of the corners was more important than top speed. As a result, he created a grand prix machine that excelled on all types of circuits.

Yet, as a classic speed bowl, Monza suited the mighty Maserati better. But Nuvolari managed to score a debut victory due to superior fuel and tyre efficiency. He also won the French Grand Prix and placed second in the German Grand Prix behind Rudolf Caracciola in a sister car. With victories in all three rounds of the European Championship and three further major race wins, the new Alfa Romeo was clearly the grand prix car to beat in 1932.

It's point proven, Alfa Romeo decided to withdraw its factory effort at the end of

Jano created a grand prix machine that excelled on all types of circuit

The bifurcated drive system removed from the racecar. This consists of a pair of propshafts connected to a centrally mounted differential



The bevel gears used on both sides of the drive in the bifurcated system are more prone to wear than other approaches, yet actually these only very rarely affected the reliability of the P3 in grand prix racing

The Roots-type superchargers, each feeding four of the eight cylinders, are mounted laterally on the intake side of the powerplant and are also driven by the central gears

Weber carbs are fitted above superchargers, feeding petrol from a 140-litre fuel tank that is fitted in the tail of the car. There is also a 20-litre oil tank for the dry-sump lubrication

the year. During the 1933 season, the Italian manufacturer was represented by Scuderia Ferrari. The privateer team initially ran 8C 2300 Monzas with little success until Alfa finally made the Monopostos available. Luigi Fagioli used one to score a repeat win in the Italian Grand Prix.

In its original guise the Alfa Romeo Monoposto was then rendered obsolete due to a substantial rule change that came into effect in 1934. Among the changes was a minimum weight set at 750kg without the driver, fuel, oil, water or tyres. A minimum body width of 850mm at the driver's seat was also imposed. The Alfa Romeo was both too light and narrow.

Both of these problems were relatively easily addressed and a second series of Monopostos were produced. The new cars were now officially referred to as the Tipo B. Confusingly, this type name was also retrospectively affixed by Alfa Romeo to the original 1932 car to indicate that it was a replacement of the Tipo A. At the time, the media also used the type name P3, as they reasoned it also replaced the P2 as raced successfully between 1924 and 1930. While the P3 type name stuck, there is no indication that Alfa Romeo ever used this name itself. In his book, in-house Alfa Romeo historian Luigi Fusi refers to the car as 'La Monoposto Tipo B (P3)'.

Ferrari development

In addition to the widened body, the 1934-specification Tipo B also featured bored out cylinders, from 65 to 68mm. This raised the displacement to 2905cc and the power to 255bhp at 5400. For 1935, the engine size was further increased. In the specification used at the 1935 German Grand Prix, the Tipo B featured a 3822cc engine, good for a staggering 330bhp. These drastic measures were necessary to keep up with the sophisticated Mercedes and Auto Union grand prix cars that were introduced in 1934. Most of the development work was entrusted to Scuderia Ferrari. Yet while works supported, the Enzo Ferrari run organisation had nowhere near the resources of the German government backed efforts. Scuderia Ferrari nevertheless introduced comprehensive revisions to the suspension design. At the front, a Dubonnet type independent suspension was fitted in 1935. This consisted of a rigidly mounted beam axle with short trailing arms connected to the axle through kingpins. The motion was controlled by an internally mounted spring and damper. At the rear, quarter-elliptic leaf springs were fitted and one of the friction dampers was substituted by a hydraulic shock absorber. Braking was also substantially improved by introducing a hydraulic system.

For the 1934 German Grand Prix at Avus, Scuderia Ferrari also developed a unique

Most of the development work was entrusted to Scuderia Ferrari

Sandwiched between the two halves of the engine is the gear-train that drives the twin overhead camshafts. Valves are mounted at a 100-degree angle, as was then the norm

P3 camshafts. As the head is symmetrical each port could serve as exhaust or intake. These were switched from the 8C 2300 spec, with intake moved from the right to left

One nose, two great names in Italian motoring. When Alfa Romeo decided it had proved its point with the P3 at the end of the 1932 season Ferrari stepped in to run it in grands prix

This is the actual racecar that beat the Mercedes and Auto Unions at the 'Ring back in 1935, one of the most famous races in the sport's history. It still competes in historics

Alfa-red the great

The P3 pictured in this feature is chassis 50005, which is among the very last Tipo Bs produced. It is one of three cars fitted from new with the Dubonnet-style independent front suspension.

Once added to the Scuderia Ferrari stable, it also received the SF45 moniker, which helped the team identify individual cars. Alfa Romeo and Scuderia Ferrari were not known for their record keeping skills, so it is virtually impossible to track the individual histories of the cars.

But Nuvolari's win in the 1935 German Grand Prix was instantly recognised as historic, so observers at the track actually made the effort of noting down the serial number of the victorious Alfa. As a result, we know with considerably certainty that this is the very car used by Nuvolari to achieve that momentous victory.

Not a man known for his sentimentality, soon after the 1935 season Enzo Ferrari sold this car in favour of newer, more competitive racing cars. Following lengthy spells in New Zealand and Japan, it was eventually acquired by American collector and historic racer Jon Shirley in 2000. Beautifully prepared for him by Dennison International Motorsports, the car has since been raced on both sides of the Atlantic by Jon and his son Erickson with great verve.

streamlined body, which helped Guy Moll win the race. But despite Ferrari's best efforts, the Tipo B was no match for the German cars, certainly not on raw pace. In reality little had changed since its debut and the qualities of Jano's original design of fine handling and reliability were still the car's biggest assets.

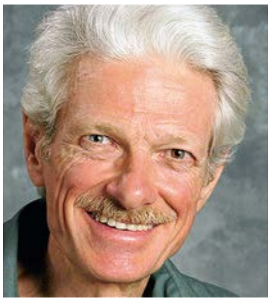
Lord of the 'Ring

For the now legendary 1935 German Grand Prix, Scuderia Ferrari entered three Tipo Bs against five cars from Mercedes and four from Auto Union. The grid was decided by ballot with Nuvolari starting on the front row sandwiched by a Maserati and an Auto Union. Shortly after the start Caracciola in one of the Mercedes W25s grabbed the lead on a drying track. Nuvolari initially kept him in sight but lost valuable time with a spin on lap two. He was stuck in sixth for several laps but then started to make up ground and passed Mercedes man Manfred von Brauchitsch in a daring move around the outside of the Karusell to take third. By lap 10, Nuvolari was in the lead and he was able to clock similar lap times to the much more powerful German rivals. The lead cars then pitted and a botched stop cost Nuvolari over a minute. But thanks to a succession of spectacularly fast laps, Nuvolari entered the 22nd and final lap with a 45-second deficit to Brauchitsch. To resist the pressure from the Flying Mantuan Brauchitsch sped up and asked too much of his rear tyres – Instead of fitting new tyres he had decided to press on. Then, at the Karussel corner, his left rear tyre exploded, handing the lead and ultimately the victory to Nuvolari, who then beat his nearest rival by a staggering 1m38s.

Art work

The 1935 German Grand Prix was the last major victory for the Tipo B, which had fought valiantly at the forefront of Grand Prix racing for four seasons. One of the other major wins for the car that year was at the Mille Miglia, where the very first Tipo B was fitted with a two-seater body. Alfa Romeo also introduced the fully independently sprung Tipo C, but despite building 12 and even 16-cylinder variants, it could do little in the face of German supremacy.

The Alfa Romeo P3 remains one of the great grand prix cars. It will be forever associated with Nuvolari and that win at the 'Ring. But above all, it is an engineering work of art that is very much a complete package, and not just the largest possible engine strapped to a simple chassis, like so many of its contemporaries.



Keeping at arm's length using the correct ratio

Pondering the problems of finding the right control arm lengths

QUESTION

On the ratio of the upper control arm length to the lower control arm length, you and Herb Adams are pretty much in agreement. Adams extends the idea a little by saying the key is to look at the swing arm length and even gives an idealised amount of 124cm, and suggests this produces the least roll centre migration. What do you think about this?

On a related idea, I'm now on to building a classic car with 27in tyres. What do you feel would be a good length for the upper and lower control arms, and if I switch to 25in tyres or 23in tyres, would this change your recommendation as to the length of the upper and lower control arm lengths? I have nothing that limits the track of my vehicle.

THE CONSULTANT

We always try for suspension properties that vary as little as possible as the suspension moves. We would like camber, caster, and jacking coefficients (geometric 'anti's') to all be constant at all possible combinations of suspension displacement and sprung structure attitude. However, that is intrinsically impossible for various reasons.

Consequently, every design is a compromise. The objective is not to make sure any of the properties stay constant, but rather to make sure that none of them vary excessively or stray into ranges that will cause serious problems.

The usual concern about 'roll centre migration' stems from the erroneous belief that the intersection of the front view force lines is always the roll centre, and that if it moves laterally, the car behaves erratically. This is not really true, actually, but if the force line slopes change rapidly, that can make the car behave erratically.

When the front view projected lower control arms are around 15 inches long, and the upper ball joint is a little below the wheel rim, and the lower ball joint is about half as far from the ground as the upper, a control arm length ratio around 2:3 (upper arm around 10 inches) will make the force line slopes stay fairly constant as the car rolls. Therefore, a 2:3 ratio is a common rule-of-thumb recommendation.

Note that if the force line slopes don't change in roll, they will change in ride by about two degrees per inch of travel. For a symmetrical car of normal proportions, that makes the roll centre approximately go up and down with the sprung structure. This demonstrates that we can't hold everything constant at once.

To make the force line slopes stay constant in ride, we need to make the control arm lengths consistent with the rule developed by Maurice Olley: upper to lower control arm length ratio should be the same as the lower to upper ball joint height ratio. If the upper ball joint is twice as high as the lower, the lower arm should be twice as long as the upper.

Strong armed

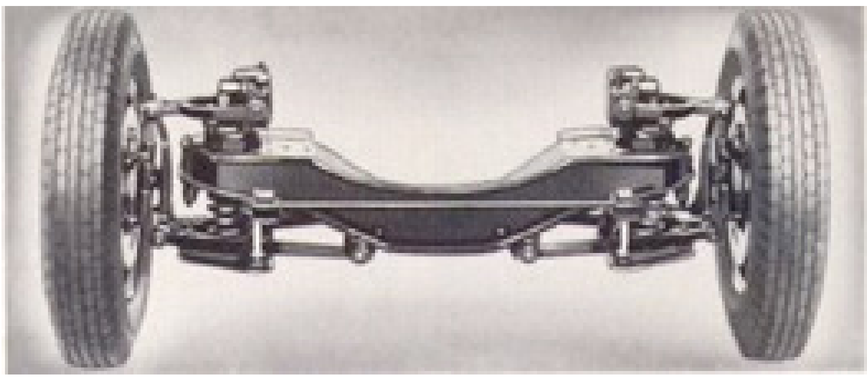
Some early Chevrolet SLA suspensions, up until 1954 (and up until 1962 on Corvettes), were built this way. In the first version of these, introduced in 1939 (see pic below), the arms have very nearly a 1:2 length ratio.

In the last versions ('54 sedan, C1 'Vette), the front view projected control arms still have about a 1:2 length ratio. The arms themselves don't have that length ratio but they have diagonal pivot axes as seen from above. At the axle plane, the pivot axes for the lowers are almost at the car's centreline and the pivot axes for the uppers are in the vicinity of the frame rails. In all versions, upper and lower front view projected control arms are close to horizontal at static ride height. The design objective here was to make the contact patches move straight up and down in normal driving, primarily to minimise tyre wear.

Bended knee

The previous 'original knee action' design, actually a Dubonnet suspension, used a simple single trailing arm that let the wheel move in a vertical plane. The 'perfected knee action' shown in the picture was a completely different system. The Dubonnet design suffered from poor structural properties, oil leakage, and severe pro-dive in braking. GM 'perfected' it by throwing it out completely and starting over. However, GM engineers thought the vertical movement was a good thing, so they were trying to keep the vertical movement while addressing the other problems.

When the control arms are all horizontal, then regardless of their length, the force lines are horizontal. Therefore they coincide and it is impossible to define a single intersection. Both wheels have jacking coefficients of zero. There is no geometric anti-roll or pro-roll. The roll centre is at ground level. If the car is cornering and rolls a bit and the force line angles exactly change angle with the sprung structure, they are then parallel and have no intersection. However, the outside wheel now has a bit of



In the first version of the Chevy SLA suspension, from 1939, the arms have very nearly a 1:2 length ratio

The objective is not to make sure any of the properties stay constant, but rather to make sure none vary excessively

It comes down to a compromise between controlling variation in jacking coefficient and controlling variation in camber properties

anti-roll and the inside one has a bit of pro-roll. Because the ground plane forces are bigger on the outside wheel, there is net anti-roll: the roll centre is just slightly above ground. If the force lines are just a hair out of parallel they have an intersection that could be miles from the car and way above or below ground. If the car moves just a little, the intersection could be miles on the other side of the car. But the jacking coefficients aren't changing much.

Roll with it

These cars exemplify a case where the force line slopes change in roll, and the so-called kinematic roll centre can migrate wildly. Yet the cars are not erratic. They lean and they plough. But they are not squirrely.

So is there a front view swing arm length (FVSA) that minimises changes in jacking coefficient, force line slope, or so-called kinematic roll centre location, as the car rolls? No, there isn't. There is no particular relationship at all.

However, there are quite a few other relationships that might be pertinent here.

FVSA does relate to changes in camber: to camber gain, or rate of camber change with respect to suspension displacement, or first derivative of camber with respect to displacement. Within the range normally seen, long FVSA gives little camber change in ride and lots of camber change in roll. Short FVSA produces the reverse: lots of camber change in ride and little in roll.

Displacement

There is a relationship between control arm length ratio and change in FVSA with suspension displacement. When the upper arm is shorter than the lower, the FVSA shortens as the suspension compresses and lengthens as the suspension extends. If the arms are parallel at static, the FVSA is undefined at static, positive and decreasing as the suspension compresses from static, and negative and increasing (or decreasing negative; decreasing in absolute value).

This produces poor camber recovery in roll on the inside wheel. In some cases camber recovery can be negative: the inside wheel leans out of the turn more than the body does, even with no static negative camber, and runs on just the inboard edge of its tread.

I like to speak of camber velocity (first derivative of camber with respect to suspension displacement) and camber acceleration (second derivative of camber with respect to displacement; first derivative of camber velocity with respect to displacement). FVSA governs camber velocity. Control arm length ratio governs camber acceleration. Note that this is my own terminology. It is not in general use and does not have SAE or ISO recognition. But If you are to use it you should be able to explain it. So using this vocabulary, here are some simple rules:

1. Making the control arm lengths more equal reduces camber acceleration.
2. Within usual ranges, making the control arm lengths more unequal reduces changes in jacking coefficients.
3. Making both control arms longer reduces both camber acceleration and changes in jacking coefficients, but uses up room and adds a bit of control arm mass.
4. Spreading the control arms further apart (longer upright) makes the system act as though the arms were more equal.
5. Lowering both ball joints will make the system act as though the arms were more equal.
6. Cars will run well with a wide range of properties in these regards, but it is desirable to make the properties as similar as possible at the front and rear.

It should by now be apparent that for most cars, control arm length ratio comes down to a compromise between controlling variation in jacking coefficient and controlling variation in camber properties. The only thing that helps both at once is making both arms longer. There will inevitably be practical limits to that, but it does pay to be aware of this early in the design process.

So what about the case where we have a car on tall tyres and we fit a set with a loaded radius an inch or two smaller, perhaps when switching from street tyres to track tyres?

Do we need different control arm lengths? In most cases, I'd say no. The car will act as though the control arm lengths were a bit more equal when we put on the track tyres, but it shouldn't be a problem.

Early Corvettes (1952 here) had upper to lower control arm length ratio the same as lower to upper ball joint height ratio

CONTACT

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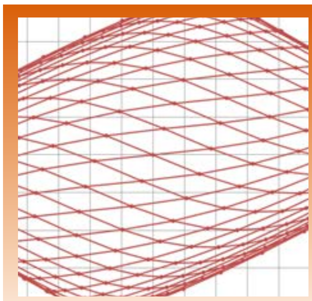


Slip Angle provides a summary of OptimumG's seminars

Getting more from your yaw diagrams

Our analysis of yaw versus lateral acceleration continues with Claude Rouelle's explanation of the yaw moment diagram and how to interpret it

We will start this article by reviewing some basic concepts. As we have seen in the previous articles on the yaw moment versus lateral acceleration method, an understeering car is defined as a car that doesn't have enough yaw moment and an oversteering car is a car with too much yaw moment. The yaw moment is caused by 12 factors, which come from the tyres: the four lateral forces (F_y), the four longitudinal forces (F_x) and the four self-aligning torques (M_z). Let's also remind ourselves that at the corner apex – i.e. where the car is closest to a steady-state – the resultant yaw moment should be equal to zero.

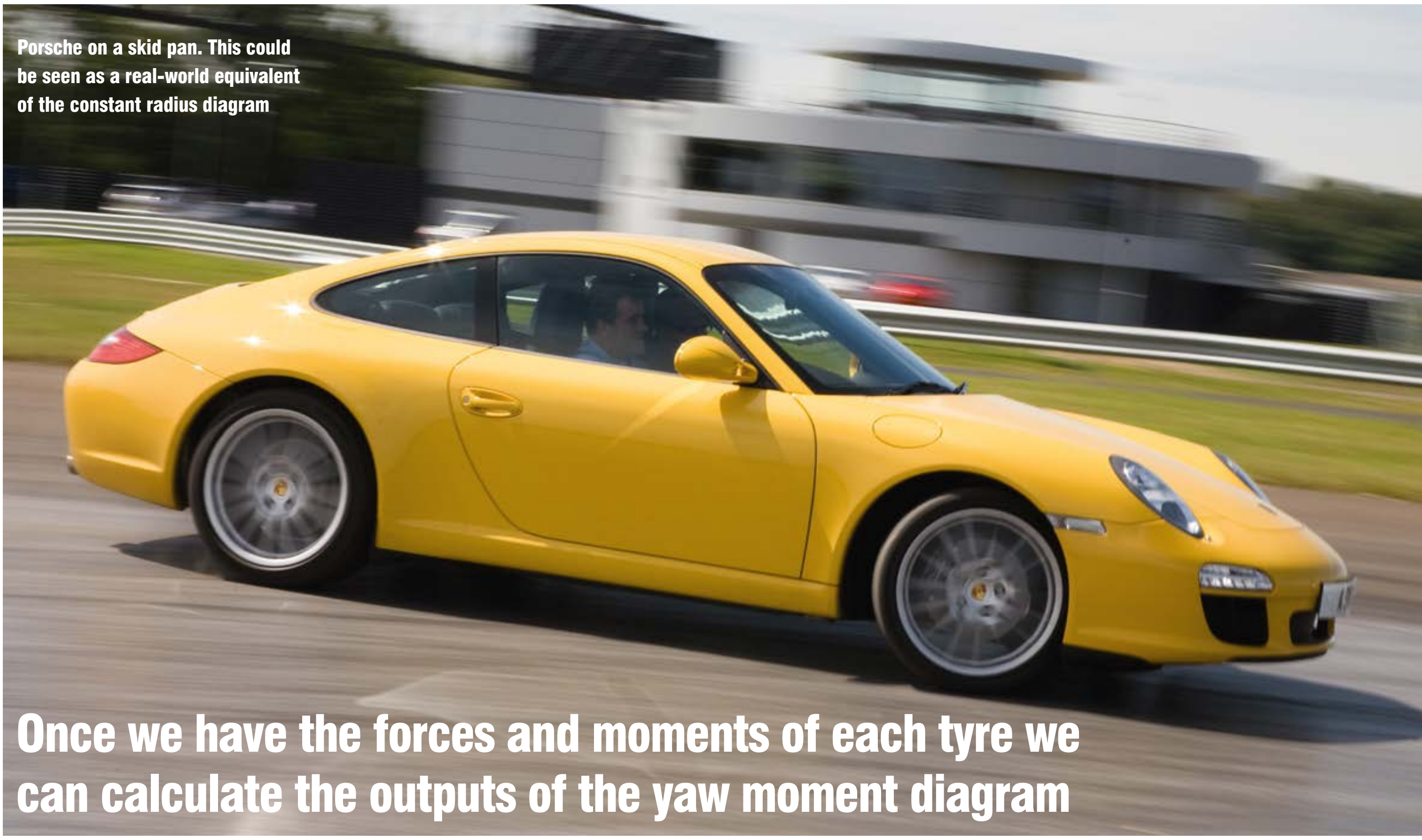
The yaw moment diagram is a 2D chart that represents two outputs: the resultant yaw moment in the vertical axis and the resultant lateral acceleration in the horizontal axis. Each point of this diagram represents a combination of two inputs: the steering angle δ and the CG slip angle (also called CG yaw angle) ß. Using the yaw moment diagram, an engineer can get a car design and set-up that can not only reach the maximum possible lateral acceleration, but also have the right amount of yaw moment at the right time during a corner.

There are two types of yaw moment diagrams: at constant speed and at constant radius **(Figure 1).** In both cases, the inputs (steering angle δ and CG slip angle) and outputs (lateral acceleration and yaw moment) are the same, but they represent different scenarios. The constant speed simulation represents the car running at a very large flat surface, while the driver tries to reach the tightest possible radius in a steady-state, neutral behaviour, at a given speed. The constant radius method represents, of course, the car at a skid pad, where the driver tries to reach the maximum longitudinal speed also in steady-state.

Let's now dive into the algorithm that generates the yaw moment diagram. As said previously, the two main inputs of the diagram are the steering angle δ and the CG slip angle ß. The procedure described in the next paragraphs must be repeated for every combination of these two parameters, within a range, to generate the full diagram. Since it is not possible to calculate the equilibrium state of the vehicle explicitly, we will need to run an iterative process until a convergence criterion is met.

Steering angle

We start by positioning the vehicle with a given steering angle δ and CG slip angle ß **(Figure 2)** at either a constant speed or radius. Then, we can calculate the slip angle of each



Porsche on a skid pan. This could be seen as a real-world equivalent of the constant radius diagram

Once we have the forces and moments of each tyre we can calculate the outputs of the yaw moment diagram

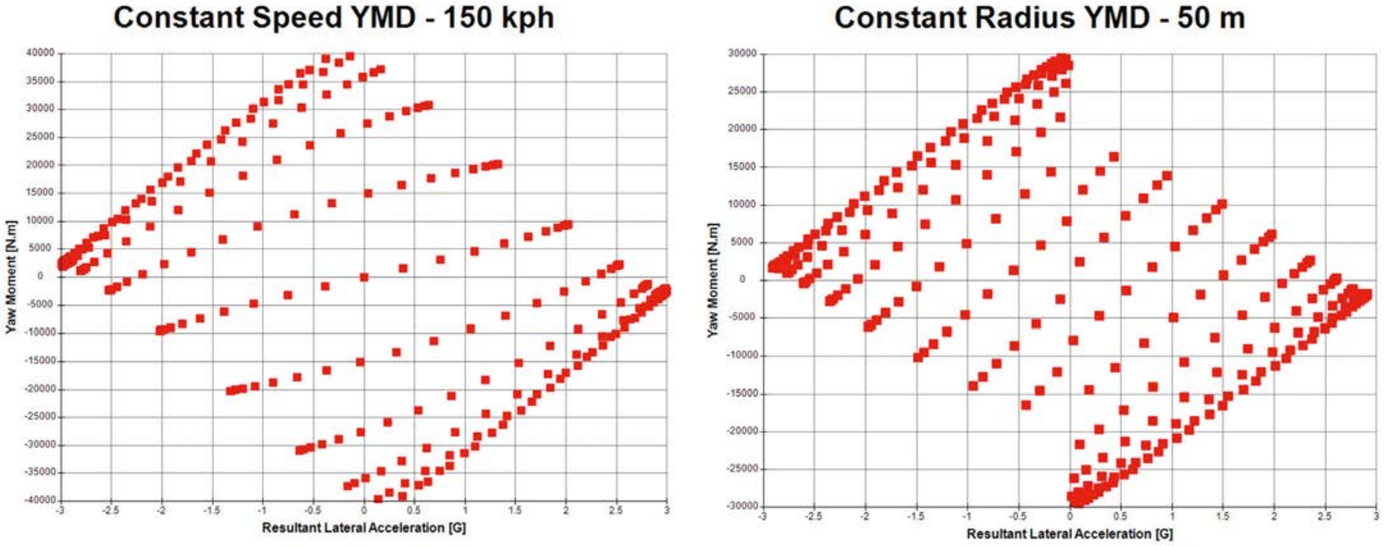


Figure 1: The two types of yaw moment versus lateral acceleration diagrams – constant speed or constant radius

tyre, providing we have some basic information about the car, such as the steering ratio, the Ackermann geometry and the toe angles of each wheel. The formulae for calculating slip angles are shown in **Figure 3**. Note that, at this stage, we assume that the vehicle has zero yaw velocity (r), which will be included in the next iterations. Basically, there are three causes for tyre slip angle: steering input (or toe angle) δ, CG slip angle ß and yaw velocity r. With these three pieces of information, we can calculate the longitudinal and lateral speeds at each contact patch and obtain the slip angle.

Each tyre slip angle comes this way **(Figure 3)**:

$\alpha LF = [V_y + (r\ a)] / [V_x - (r\ T_f/2)] - \delta_{LF}$ (9)

$\alpha RF = [V_y + (r\ a)] / [V_x + (r\ T_f/2)] - \delta_{RF}$ (10)

$\alpha LR = [V_y - (r\ b)] / [V_x - (r\ T_r/2)]$ (11)

$\alpha RR = [V_y - (r\ b)] / [V_x + (r\ T_r/2)]$ (12)

This is where V_x and V_y are the longitudinal and lateral car CG speed, T_f and T_r are the front and rear tracks, *a* is the distance from the front axle to the CG, *b* is the distance from the CG to the rear axle, ß is the CG slip angle, *r* is the yaw velocity and δ_{LF} and δ_{LR} are the left front and right front steering angles. In this case the bump steer and the compliance are not being considered.

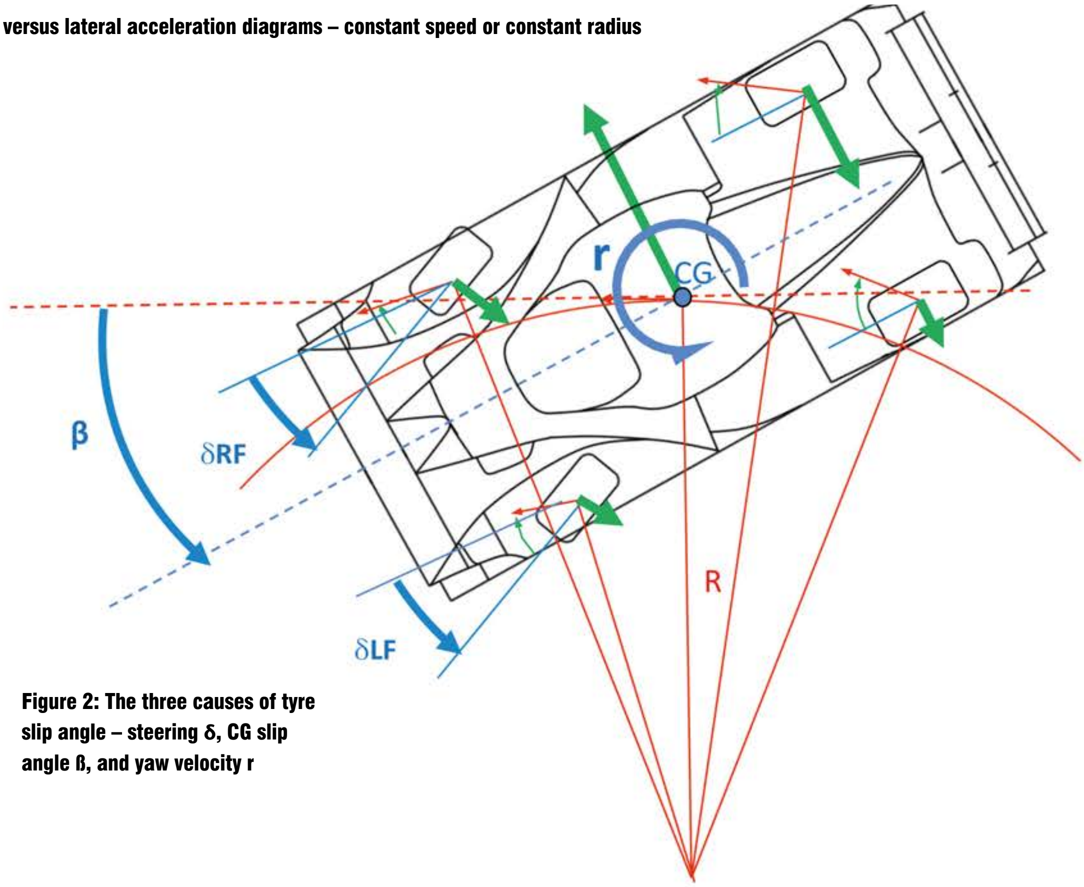


Figure 2: The three causes of tyre slip angle – steering δ, CG slip angle ß, and yaw velocity r

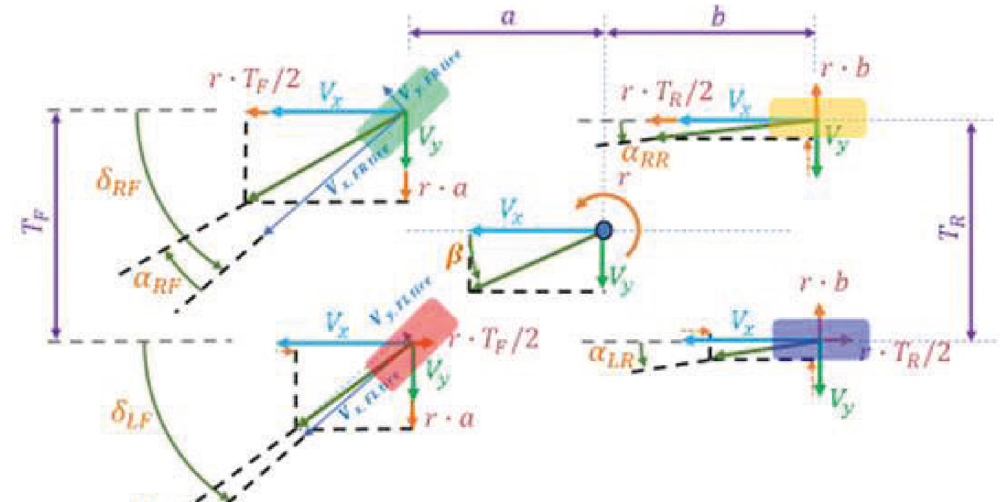
Black magic

Once we have the slip angles we can proceed to calculate the forces and moments of each tyre. To do so, we can use a simple 'magic formula' tyre model. The magic formula tyre model will receive as inputs the tyre slip angle α, the vertical force Fz, the camber angle γ and the slip ratio κ (which, in this case, is zero). Some tyre models can also include effects of speed, pressure and temperature, but let's keep it simple for now. The tyre model will then return the values of lateral force (F_y), longitudinal force (F_x) and self-aligning moment (M_z).

Now that we have the forces and moments of each tyre, we can calculate the outputs of the yaw moment diagram: the lateral acceleration and the yaw moment. However, since the resultant lateral acceleration is (most likely) different than zero, the values of vertical forces that we initially used in the tyre model for calculating the forces and moments are no longer correct. The lateral acceleration will cause a lateral load transfer, which will modify the vertical loads on each tyre. The inclination angles will also be different, as the lateral acceleration results in a roll angle. Even the resultant slip angles will change, since now we have a yaw velocity r = Ay/Vx. If we are running a constant radius simulation, the new value of longitudinal speed must also be calculated ($V=\sqrt{(A\ R)}$). Thus, we need to update all these values and recalculate the forces and moments of the tyres. We iterate through this process until the imposed lateral acceleration matches the resultant lateral acceleration. More details on this algorithm are explained in the OptimumG seminars.

It is worth mentioning that the accuracy and usefulness of the yaw moment diagram will change depending on how complex our vehicle model is. You can, for example, consider effects such as suspension kinematics (bump steer, camber change, etc.), compliance, changes in aerodynamic forces with ride heights, chassis stiffness,

The lateral acceleration will cause a lateral load transfer, which will modify the vertical loads on each tyre



$$V_y = V_x \cdot \beta$$

$$\alpha_{RF} = \frac{V_y + r \cdot a}{V_x + r \cdot T_F/2} - \delta_{RF} \qquad \alpha_{RR} = \frac{V_y - r \cdot b}{V_x + r \cdot T_R/2}$$

$$\alpha_{LF} = \frac{V_y + r \cdot a}{V_x - r \cdot T_F/2} - \delta_{LF} \qquad \alpha_{LR} = \frac{V_y - r \cdot b}{V_x - r \cdot T_R/2}$$

Figure 3: Tyre slip angle calculation

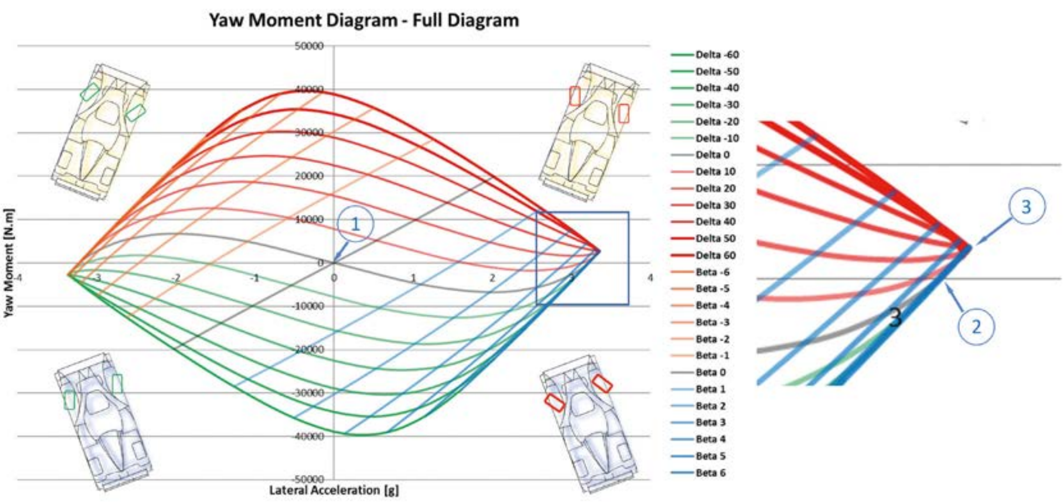


Figure 4: Yaw moment diagram at constant speed with CG slip angle and steering isolines

longitudinal acceleration, etc. As a general rule, the more complex the vehicle model is, the more sensitivity analysis we can perform.

Once we calculate the vehicle state for every combination of steering angle δ and CG slip angle ß, we will have the full yaw moment diagram. Ideally, some measurements made on track can help us to decide the realistic window of inputs. To better visualise the diagram, we usually connect lines with same CG slip angle or same steering angle, as shown in **Figure 4**.

Point taken

Even though we calculate the full yaw moment diagram, we are usually only interested in a few of its points. Obviously, we don't know which points will fall in the regions of interest prior to the simulation, that's why we compute all of them. **Figure 4** shows three points that we often watch for, when interpreting a yaw diagram of constant speed.

At point 1, we see that the intersection of the isoline $\delta = 0$ and the isoline ß = 0. This point usually corresponds to the origin of the outputs, where both lateral acceleration and yaw moment are equal to zero. That seems logical: at constant speed with no yaw angle and no steering input the car should be travelling in a straight line; the turn radius is infinite. There is an exception: if the car is asymmetrical (in NASCAR or Indycar, on ovals, for example) it is possible that, even without any steering or CG slip angle input, the car would have a small amount of yaw moment and lateral acceleration. This point is particularly important because we can take conclusions about the behaviour of the car as it enters the corner. This subject will be further explored in the next article.

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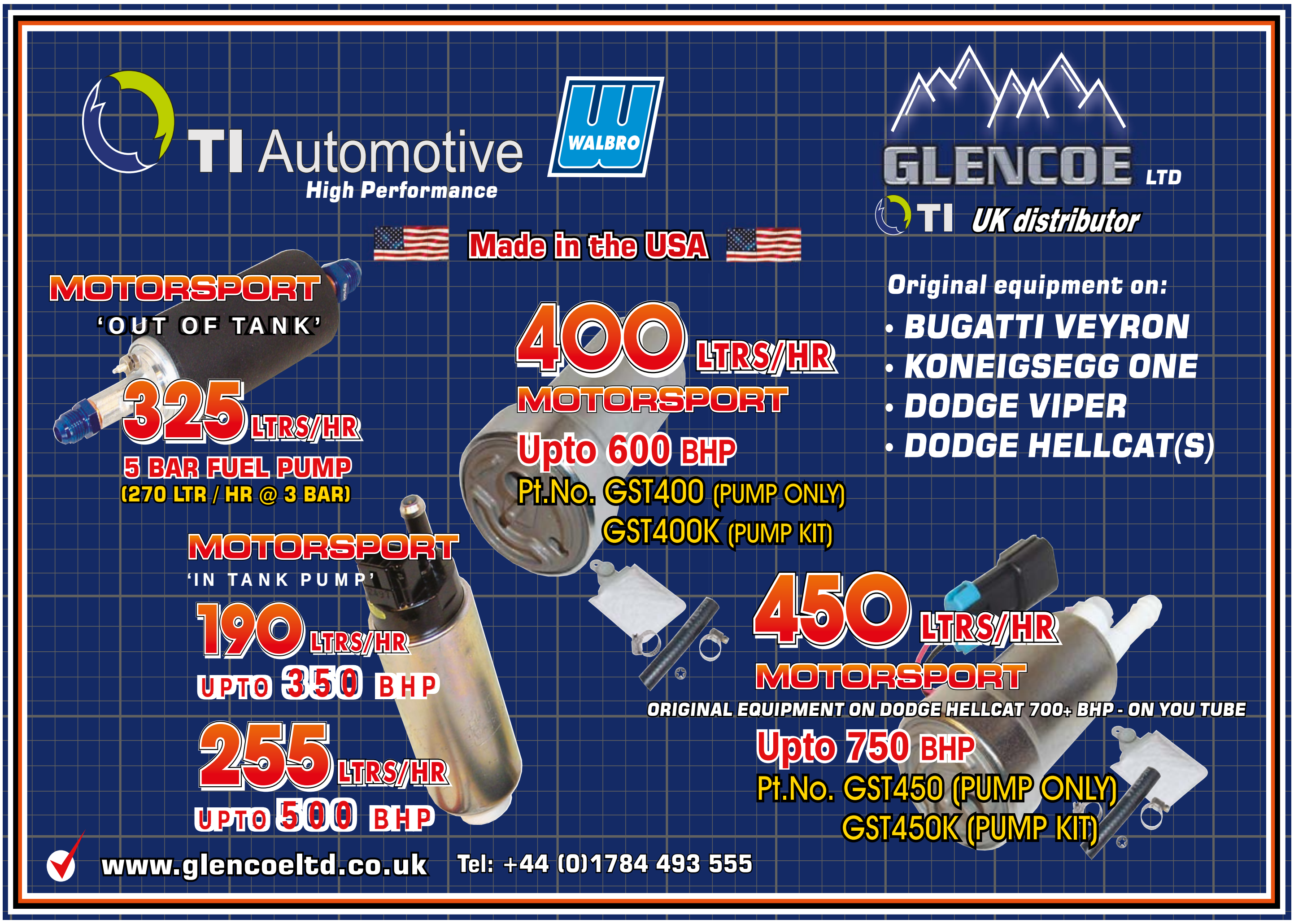
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Optimising the aero on a UK hillclimber

The latest DJ Firestorm hill racer gets the wind tunnel treatment

In the Spring of 2011 we evaluated the aerodynamics of the original DJ Firestorm hillclimber, a car that went on to take a number of British Hillclimb Championship (BHC) Top 12 Run Off wins with 3.2-litre V8 Cosworth XD power. During early concept discussions on the car, another engine considered was the ex-DTM 2.5-litre V6 Cosworth KF. This was the lightest and most compact option then available, and it had already won the 2001 and 2002 BHCs in the rival Gould GR51 chassis. Despite lacking power and torque compared to the now very popular 3.5-litre V8 NME, it was chosen for the latest DJ Firestorm to propel the 2015 British Hillclimb Champion Alex Summers and his father Richard on their current campaign. At time of writing the new car was fourth overall with two second places, two thirds and numerous good placings.

The wing package on the latest car was comparable to the original Firestorm at the rear except that the upper wing tier was of a more potent profile (which the original car had subsequently adopted), with a legal maximum 1400mm span dual tier set-up. At the front it was running a more modest front wing configuration, utilising the same maximum permitted 1500mm overall width main element plus endplates but with a more modest part-span single flap arrangement. The smaller engine not only meant a more compact and nimble chassis but it also facilitated the fitting of the underbody and sidepods of the car's smaller engined cousin, the Firehawk.

Efficiency drive

The drivers' impression of the new Firestorm's aerodynamics was that it had sufficient total downforce, so given that the car has less power than its rivals, one of the main objectives of the session was to aim for best efficiency rather than maximum overall downforce. Naturally, a good aerodynamic balance was also in mind.

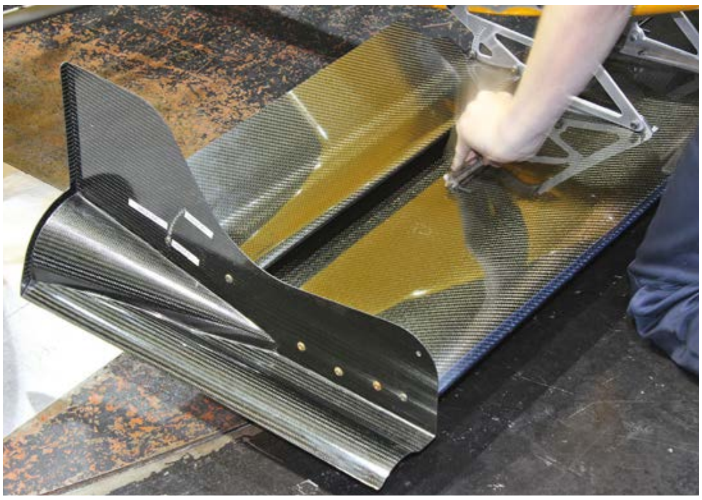
So how would the baseline aerodynamic numbers stack up? **Table 1** shows the basic data in the configuration used most recently on track, and the numbers from towards the end of our session in what appeared to be a better balanced set-up, the details of which we shall delve into in subsequent issues. Also shown for comparison are the baseline numbers obtained on the original Firestorm.

In 'as delivered' trim, the car appeared to have a too far to the rear downforce bias, with 28.9 per cent of its total downforce on the front axle. The static weight distribution with driver aboard was around 40 per cent front, hence the usual target aerodynamic balance would be around 37-38 per cent front, which is what was achieved in the 'best' configuration. This also yielded a 10 per cent drag reduction and a slightly better efficiency level, as indicated by the improvement in the –L/D figure from baseline to best, although total downforce was reduced because, in part, this was done with a rear wing flap angle reduction. Higher downforce levels with a comparable balance would be attainable if required.

Back to back

The comparison with the baseline numbers on the original Firestorm is interesting; that car already had a higher per cent front value but this was principally because rear downforce was lower, the result of the less potent upper rear wing profile at that stage. So fitting the higher downforce upper rear wing and bringing the front and rear into better balance produced an -L/D value some 30 per cent better than the original car's baseline figure, which meant we were certainly making some progress.

The 2.5-litre V6 motivated DJ Firestorm hillclimber being tested in the MIRA wind tunnel



The front wing features a single part-span flap. Drivers say the car has good downforce

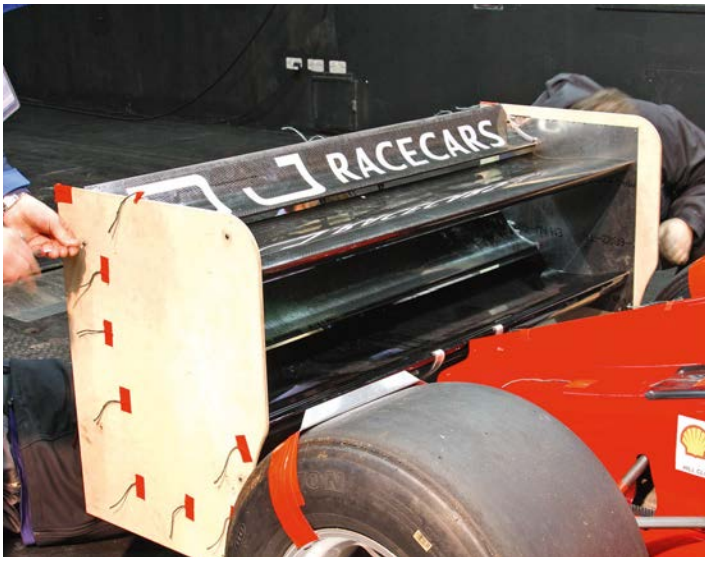
Table 1: Baseline and 'best' numbers on the latest DJ Firestorm compared to the original baseline data

	CD	-CL	-CLfront	-CLrear	%front	-L/D
Baseline	0.775	1.892	0.547	1.345	28.9%	2.443
'Best'	0.699	1.741	0.650	1.091	37.3%	2.492
Original	0.759	1.455	0.582	0.876	40.0%	1.917

One of the main objectives was to aim for best efficiency rather than maximum overall downforce

The original DJ Firestorm (pictured above) featured a two-flap front wing arrangement

The new Firestorm's upper rear wing tier had a higher downforce main element than the original car's baseline set-up. It makes use of the legal maximum span of 1400mm



The original Firestorm started its hillclimb life with a more modest upper rear wing profile

Table 2: The changes in coefficients going from a 45mph to an 80mph test speed

	Δ CD	Δ -CL	Δ -CLfront	Δ -CLrear	Δ %front*	Δ -L/D
Δ value, counts	-37	-23	+18	-41	+1.3%	+83

*Absolute rather than relative difference in percentage front.

With frequent low speed corners on UK hillclimbs it was decided to briefly examine the car at a lower than usual test speed

With frequent low speed corners as well as fast curves on UK hillclimbs it was decided to briefly examine the coefficients and forces at a lower than usual test speed, in this case 20m/s (45mph), and compare with the values measured at the usual tunnel maximum of 35m/s (80mph). **Table 2** shows the differences (as Δ or delta values) in 'counts', where 1 count is a coefficient change of 0.001.

Flow attachment

So, at the higher test speed the drag coefficient and the total downforce coefficient (-CL) both reduced, and the front downforce coefficient increased while the rear coefficient decreased.

Let's speculate on some potential mechanisms. For the front to have seen an increase in –CL at the higher speed, the simplest explanation is that the flows under the front wing were better developed and better attached at that higher speed. This is not an altogether unusual occurrence. Explaining how the rear –CL value decreased by the amount that it did at the higher speed is not so simple. In part it is likely that the increased front –CL mechanically off-loaded the rear slightly, but the extent of the rear decrease relative to the front increase, and the CD reduction, mean other mechanisms were involved. It may also be that better flow attachment under the front wing produced increased upwash that had a negative downstream effect on the underbody and/or the rear wing.

But a related observation may suggest another contributor. It was noticed that the car's suspension compressed quite markedly as air speed was increased. So could it be that dynamic ground clearance reduction coupled with the boundary layer along the wind tunnel's fixed floor conspired to restrict the mass flow into the underbody? This might have also produced a reduction in the rear –CL, and trials on ride height adjustments later in the session – which we shall examine in a subsequent issue – tend to support this notion.

In passing, it might be of interest to note that at just 20m/s (45mph) approximately 660 Newtons (148lb) of total downforce was generated in baseline configuration. This represented around 13 per cent of the weight of the car plus the driver. Compare that, for example, to the BTCC Subaru Levorg, which generated downforce equivalent to around 1.6 per cent of the car plus driver weight at 45mph, and the relative importance of low speed aero in UK hillclimbing becomes very apparent.

Look out for more on this car next month.

Racecar's thanks to Richard and Alex Summers and the DJ Engineering crew.

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In these pages he uses data from MIRA to discuss common aerodynamic issues faced by racecar engineers

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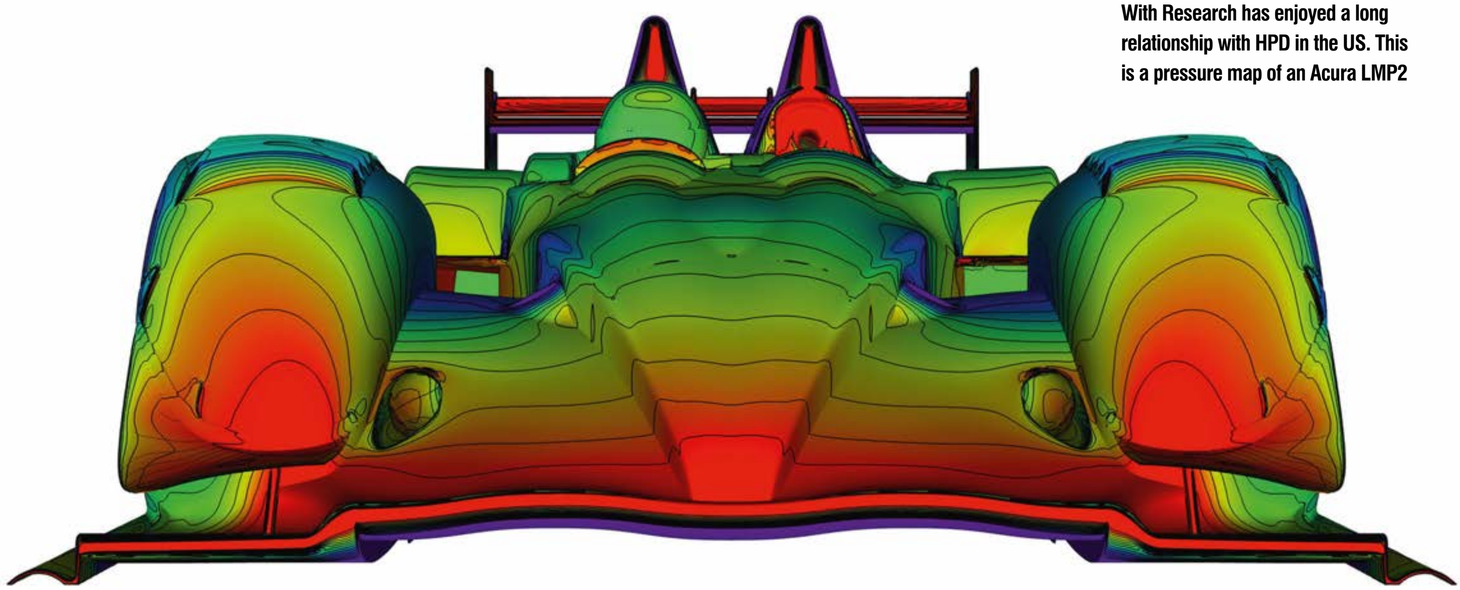
Wirth the effort

If you're in need of an overview of the development of CFD in motorsport, then you could do a lot worse than tracing Wirth Research's application of this technology over the years

By SIMON MCBEATH



With Research has enjoyed a long relationship with HPD in the US. This is a pressure map of an Acura LMP2

It is somewhat ironic that when Wirth Research decided to set up an in-house CFD department, shortly after the company was founded in 2003, the initial target was non-motorsport markets, for it is a well-known fact that the aerodynamics of the Virgin VR-01 Formula 1 car were entirely developed by Wirth Research (WR) with CFD.

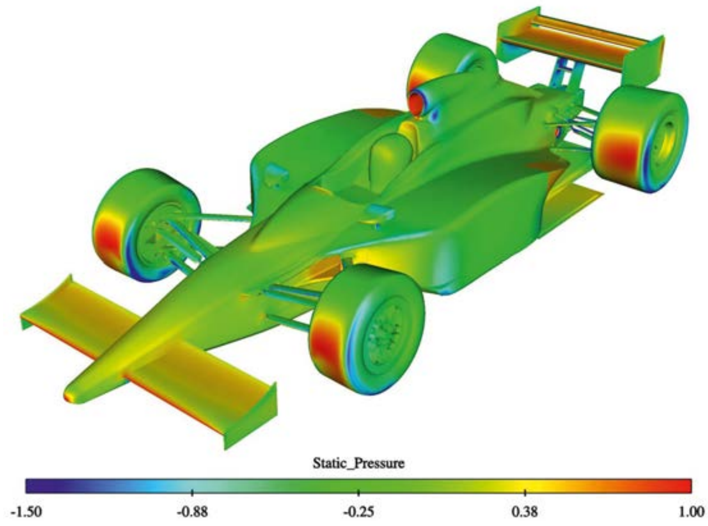
Perhaps less widely known is that cars in other top categories with which WR have been intimately involved have also been developed solely with CFD. But it is in part thanks to the company's involvement in non-motorsport markets that some of the developments that have helped improve its motorsport aerodynamics simulations have come about. We took a trip down memory lane with WR's engineering manager, Rob Rowsell, to see how the power of CFD has burgeoned in the intervening years.

Indy beginning

Wirth Research's early days at its Bicester, UK, headquarters saw it commence a long term partnership with Honda Performance Development (HPD) in the USA, working initially on the aerodynamics of the Dallara IndyCar, which in those days was competing with chassis from G-Force and Panoz. The programme used the 50 per cent scale wind tunnel at ARC, Indianapolis, and the full scale wind tunnel at FKFS, Stuttgart, Germany, out-sourcing its supporting CFD requirements at that time to Advantage CFD, in nearby Brackley.

Successful though this collaboration was, netting the 2004/5 Driver and Engine Manufacturers' Championships for HPD/Andretti Green Racing, a review of the different aerodynamic simulation tools revealed the manner in which each was applied and the relative standing of each. The tools were used according to their respective strengths at the time, so the 50 per cent scale wind tunnel was used for the majority of development work, supported by CFD to generate ideas and detail analysis, and the full-scale wind tunnel (FSWT) was used for validation. This basic process was to persist for the next few years.

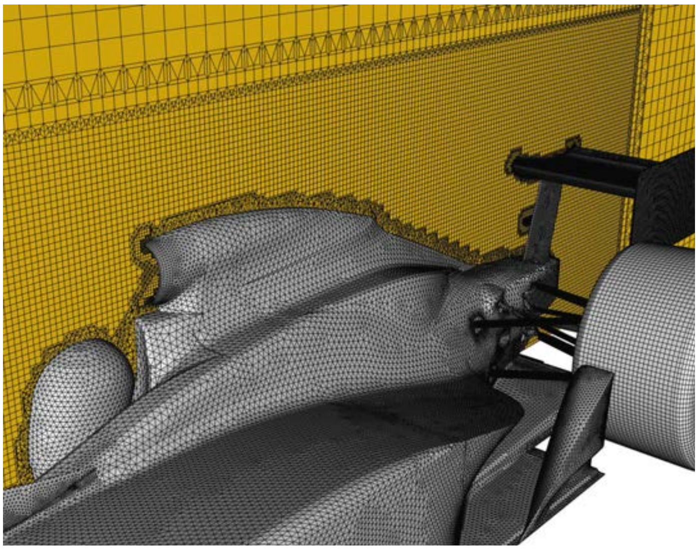
At this stage the IndyCar CFD model featured a mesh of just 15 million cells (12 million for half car models) with no boundary layer modelling and a basic turbulence model.



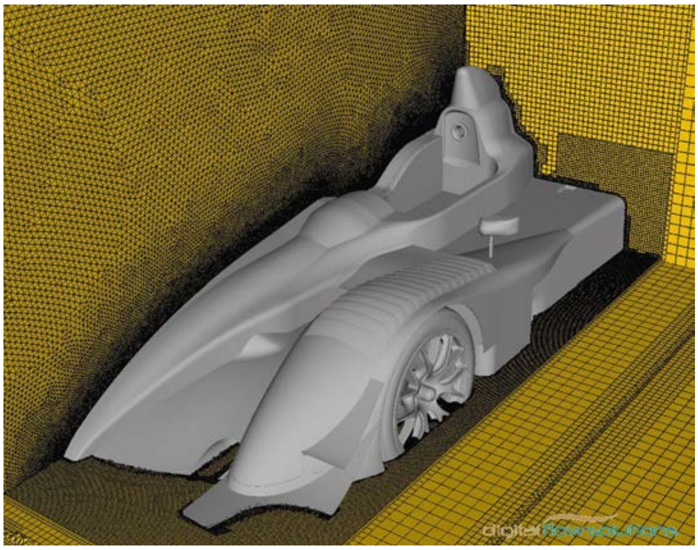
Early work: Wirth's surface pressure distribution plot of the 2004 Dallara IndyCar

It still took a 24-node cluster around 20 hours to produce a converged solution, so at this stage the accuracy and productivity available from CFD simulations was subordinate to what could be done in the 50 per cent wind tunnel.

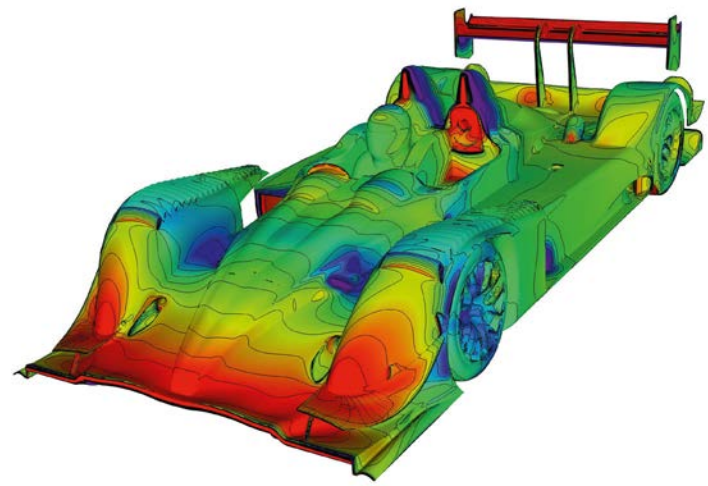
In 2004 Rob Rowsell was recruited to set up a CFD department for Wirth Research to invest in and develop in-house CFD technology beyond the level that other providers were able to offer. Despite the original plan being to cultivate markets outside motorsport, founder Nick Wirth persuaded HPD to use this now very capable in-house CFD department

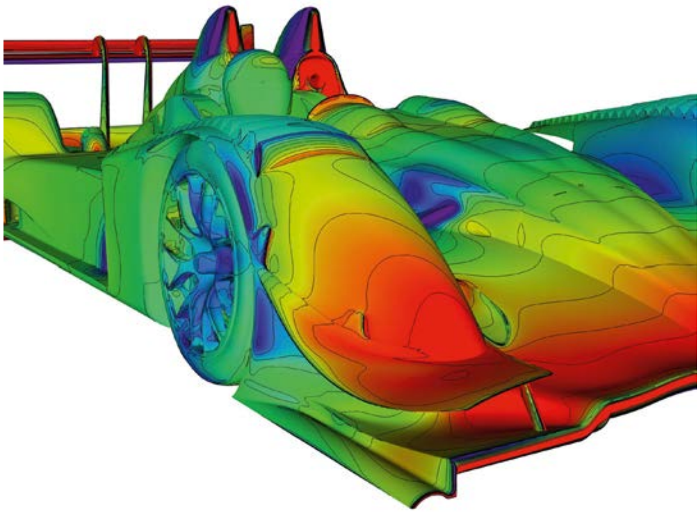


The surface mesh and a slice through the volume mesh on the 2004 Dallara IndyCar



Slices through the volume mesh on the 2007 ARX-01a LMP2 sports prototype racer





Above and right: surface static pressure distribution over the 2008 ARX-01b LMP2

to look at the LMP2 sportscar aero development in the ALMS in 2006

The development would once again use the ARC 50 per cent scale wind tunnel, with the FKFS full-scale facility used for validation, but now the CFD development support would be carried out in-house using continually improving resources.

A pilot LMP2 aero project was set up using a known LMP2 car model (and wind tunnel data) as the basis, updated to the regulations then current, to develop the applicable CFD methodology while also building a knowledge base of LMP2 aerodynamics. WR was then tasked with evaluating a range of contemporary LMP2 customer cars.

This resulted in HPD choosing to purchase a Lola LMP2 car for engine development and WR was requested to use a Courage LC75 as the basis for chassis and aero development. Rob Rowsell: 'We had expected small tweaks but having received both cars and assessed their aero in CFD, and physically in both the full scale wind tunnel and on track, we ultimately realised that we would have to develop all the bodywork to address fundamental issues including aero performance, porpoising, brake, engine and exhaust cooling, and the structural integrity of the splitter. We took on the works Porsche Spyders and became very competitive.'

The car, the Acura ARX 01a, later known as the HPD ARX 01, which was based on the Courage chassis, debuted at Sebring in 2007, winning the class and gaining second overall.

In preparation for the 2008 season, development of what became the ARX 01b began in mid-2007. 'The design encompassed a new one-piece magnesium alloy transmission and bellhousing, quick change front and rear bodywork, overall weight reduction, and all-new aerodynamics, this developed using CFD only. The result was a car that was over three seconds a lap faster than the previous car in testing at Sebring,' Rowsell says.

By now CFD mesh densities and boundary layer modelling at WR had seen significant improvements and results from CFD were closer to the full-scale wind tunnel results than were those from the 50 per cent scale wind tunnel. Furthermore, CFD was able to capture flow separations on the rear wing, and productivity had also overtaken what was possible with scale model testing, with the time from generating an idea to obtaining test results from a major part like a rear wing or a splitter being two to three times faster now with CFD.

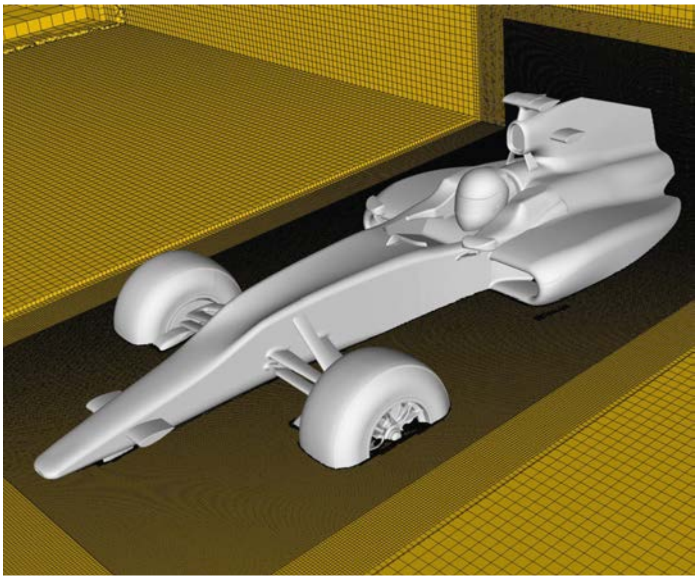
'This,' says Rowsell, 'was partly down to chasing correlation issues with the 50 per cent scale tunnel, which wasted development time.'

The ARX 01b won its class in the first race at Long Beach in 2008 and won overall for the first time at the North East Grand Prix, Lime Rock Park. It was beaten by just one point to the Manufacturers' title by Porsche.

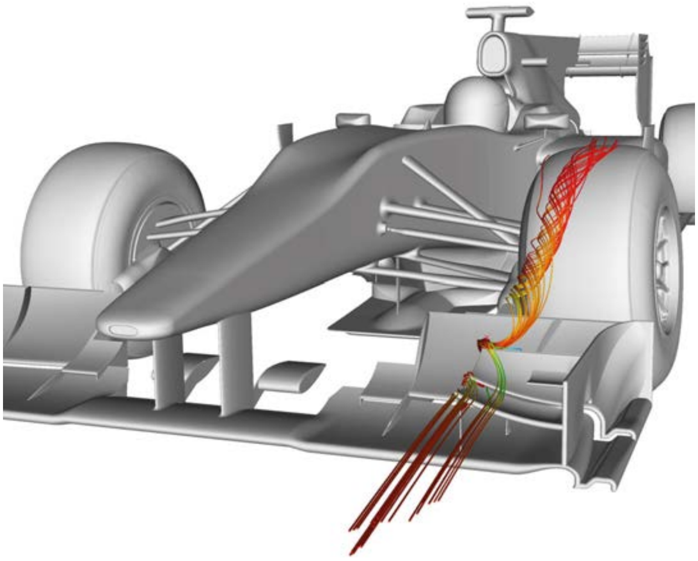
During 2008 development of the ARX 02a LMP1 car began. Much has been written in *RE* and elsewhere about the early curtailment of the 02a programme, but it did win the overall Drivers', Teams' and Manufacturers' ALMS titles in 2009. The car was essentially developed in CFD, now with track testing for validation, and required a strong front end aero package to help load up the front wheels, fitted with rear-sized tyres to increase contact patch area.

From the CFD standpoint, a switch was made to using full car models after issues on stall prediction were encountered in half-car simulations.

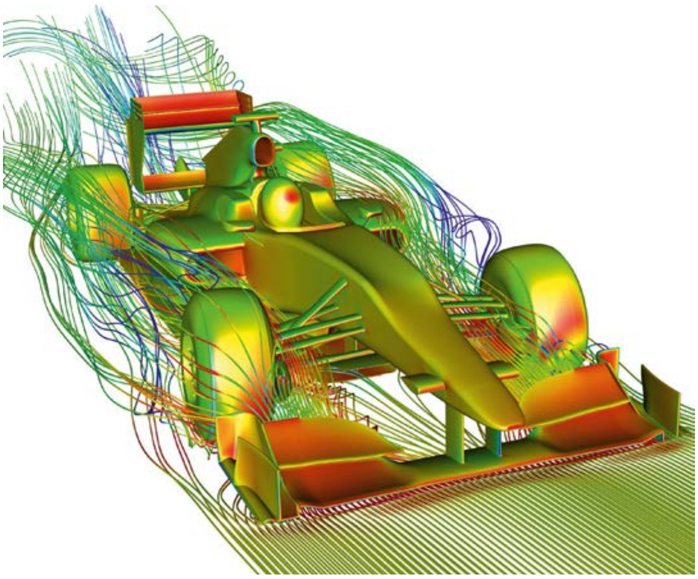
At this stage the IndyCar model featured a mesh of just 15 million cells



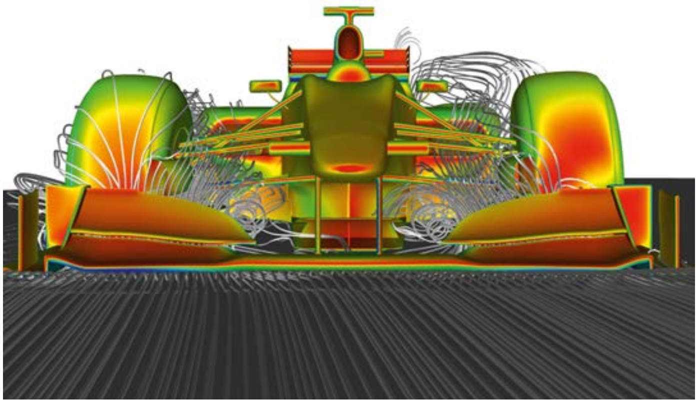
Slices through the volume mesh on the 2010 Virgin (Manor) VR-01 Formula 1 racecar



Streamlines show path of vortex formed from the front wing upper winglet on the VR-01



Surface static pressure distribution and streamlines over the 2010 VR-01 Formula 1 car



Here the y-250 vortex is readily apparent; it is emanating from the inboard end of the front wing flap of the VR-01 F1. The car's aerodynamics were entirely designed in CFD

This necessitated significant hardware upgrades to handle the much bigger cell counts and solver burden.

A further internal review in 2009 of the state of the art in the aero development of ALMS cars found that CFD results were now matching full-scale wind tunnel testing results. Furthermore, CFD and track testing had identified issues with scale model testing, including solid tyres that did not correlate with real, deforming tyres; the low speed (low Reynolds number) of the scale wind tunnel causing problems with splitter results; and there were correlation issues with dive planes and the rear wing and rear end of the car. In short, 50 per cent scale wind tunnel testing was dropped. Even full scale wind tunnel testing had weaknesses sufficient to prompt the switch to track testing for validation. This experience clearly helped define the strategy that was employed on subsequent projects.

Formula 1 beckons

With wind tunnel testing now essentially a thing of the past, the spotlight was focussed on the sole use of CFD for aero development, and became a major talking point around the Manor GP/Wirth Research/Virgin Racing entry into F1 in 2010.

The aero development work on what became the Virgin VR-01 was obviously done pre-2010, and the car became one of three new teams' entries to appear on the 2010 grid. By now mesh cell counts had progressed from the tens to the hundreds of millions of cells, with hardware investment constantly having to keep up in order to achieve satisfactory solution times and productivity.

Having said that, wind tunnel testing had been dropped from the development phase, a project was run at Southampton University wind tunnel on wheels/tyres in isolation in order to gain force data and wake velocity data (using particle image velocimetry, PIV) to validate the CFD.

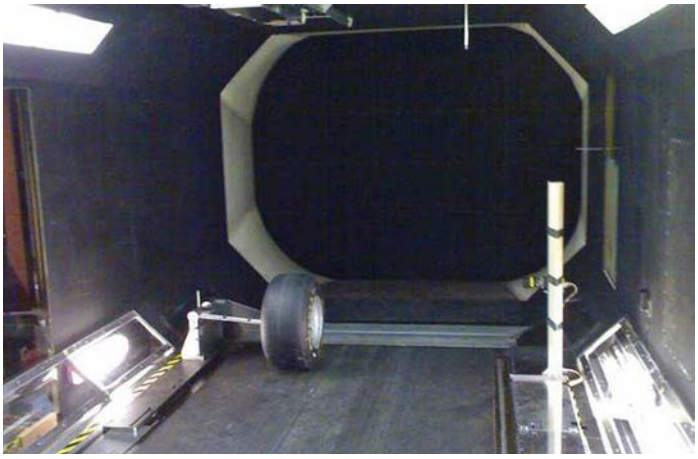
Flow separations and wake development on open wheels have always been challenging areas for CFD to handle, as well as being of much greater significance to aero performance than on closed wheel sportscars, so it's no surprise to learn that some validation was sought, and this would have been applicable to IndyCar as well as F1. Validation of the F1 car's aerodynamics was also carried out in the FKFS Stuttgart facility.

During the F1 development period WR increased the cell density in its simulations further to increase accuracy. At that time the maximum cell count was limited by the memory capacity of the computers used for meshing, so the increased mesh density necessitated a temporary switch back to using half-car models.

By 2011 the cell count on the Formula 1 model had reached 400 million cells. One of the benefits of this increase in cell density was that vortical flows were defined more effectively, this being a key aspect in the aerodynamic development of modern, high-level single seaters.

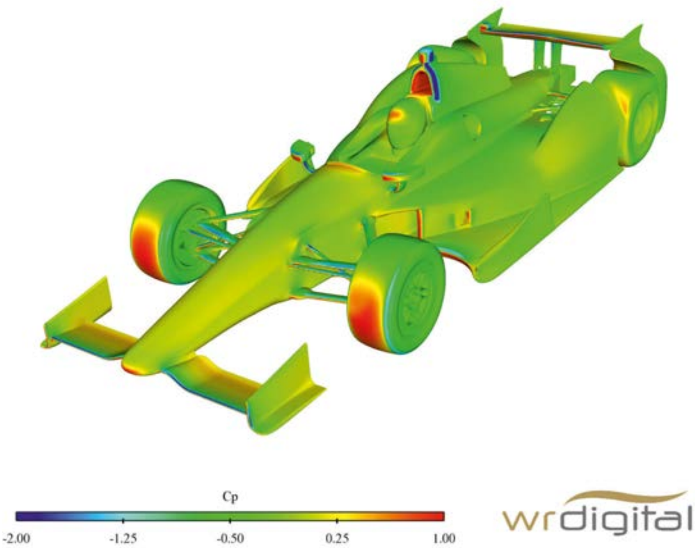
All the new developments implemented on the F1 CFD model were validated with flow visualisation tests on the real car on the race track, and were supplemented with pushrod loads, pressure tappings, flow visualisation fluid, and video footage of wool tufts. And, for example, flow separations on rear wings were found to tally well with reality.

CFD and track testing had identified issues with scale model work

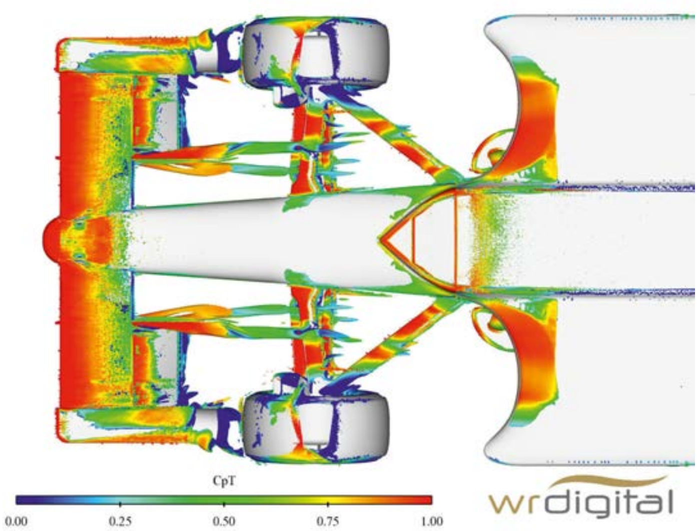


While the design development for the F1 project was all CFD the validation work on isolated wheels and tyres was carried out in the wind tunnel at Southampton University

Some validation of the full-scale F1 car's aerodynamics was carried out in the FKFS Stuttgart facility in Germany. Flow visualisation validation at the track was also used



This shows the surface static pressure distributions on the 2012 Dallara IndyCar



This is the total pressure plot showing flow details on the 2012 Dallara IndyCar

Among other ongoing developments around this time was automatic surface meshing using techniques developed in-house following months of R&D work on new CAD generation methods; bespoke data conversion software; surface mesh generation software and settings; and boundary layer generation settings. The result of this was tangible improvements in productivity. So while the stay in F1 may have been quite short, CFD methodologies were being pushed to new levels and other development programmes would feel the benefits.

This was true of the 2011 IndyCar aero development project on the latest car from Dallara, which directly benefited from the F1 recipe. The IndyCar was simpler than the F1 yet required a mesh count of 250 million cells at this stage to analyse the flows to the same level of detail. IndyCar had become an engine competition again, so WR was once again working with HPD, capitalising on the recent Formula 1 experience. The first year on this project was spent mapping the car and doing correlation work in the sophisticated full-scale Windshear wind tunnel in Concord, North Carolina to help provide teams with set-up data. This car started racing in 2012 but, as has been documented, the upgraded aero kits were delayed until 2015.

History can be a hard judge, but while many seem to perceive Virgin Racing's inability to score points during its two years in F1 as a failure, it can also be said that it succeeded in qualifying for, and finishing grands prix, on occasions beating the other two new entrants in 2010, Lotus Racing and Hispania Racing. And while, following its divorce from Wirth Research in mid-2011, Virgin Racing switched to the traditional use of scale wind tunnel testing to supplement CFD development, might it not have been possible that with better overall resources a CFD-developed F1 racecar could have been successful at that time? Today's restricted wind tunnel time and greater reliance on CFD suggests perhaps so.

Rowsell makes the pragmatic point that one of the big factors that pushed Wirth Research on the 'CFD only for development' route, with wind tunnel or track testing used for validation, was to allow customers' budgets to go further. 'One could spend a fortune using CFD, wind tunnel and track testing [for development]. When we stopped using scale model testing for the IndyCar and sportscar programmes it was a combination of correlation issues and cost that made CFD more cost effective, and ultimately it became more accurate. When we entered F1 one of the main reasons we adopted the much talked about "CFD only for development" approach was that the cost of a wind tunnel model to begin the aero programme would have eaten most of the budget before we even started.'

Beyond motorsport

As part of the company's plan to diversify, forays into two very different industries ultimately led to improvements in the simulation methods WR could bring to its motorsport applications.

In 2011 a project with Eddie Stobart was started, the transport and distribution company now operating a fleet of over 2500 trucks from its English base on a pan-European network. The brief was simple: reduce CO_2 emissions (from which, obviously, economy benefits would also accrue).

So WR applied the energy efficiency tools it had developed in its motorsport applications. In brief, a truck was scanned, a drag-reducing

Wirth Research CFD methodologies were being pushed to new levels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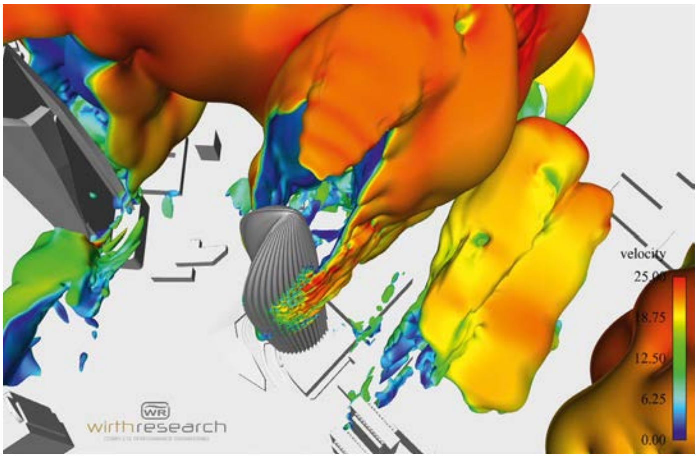
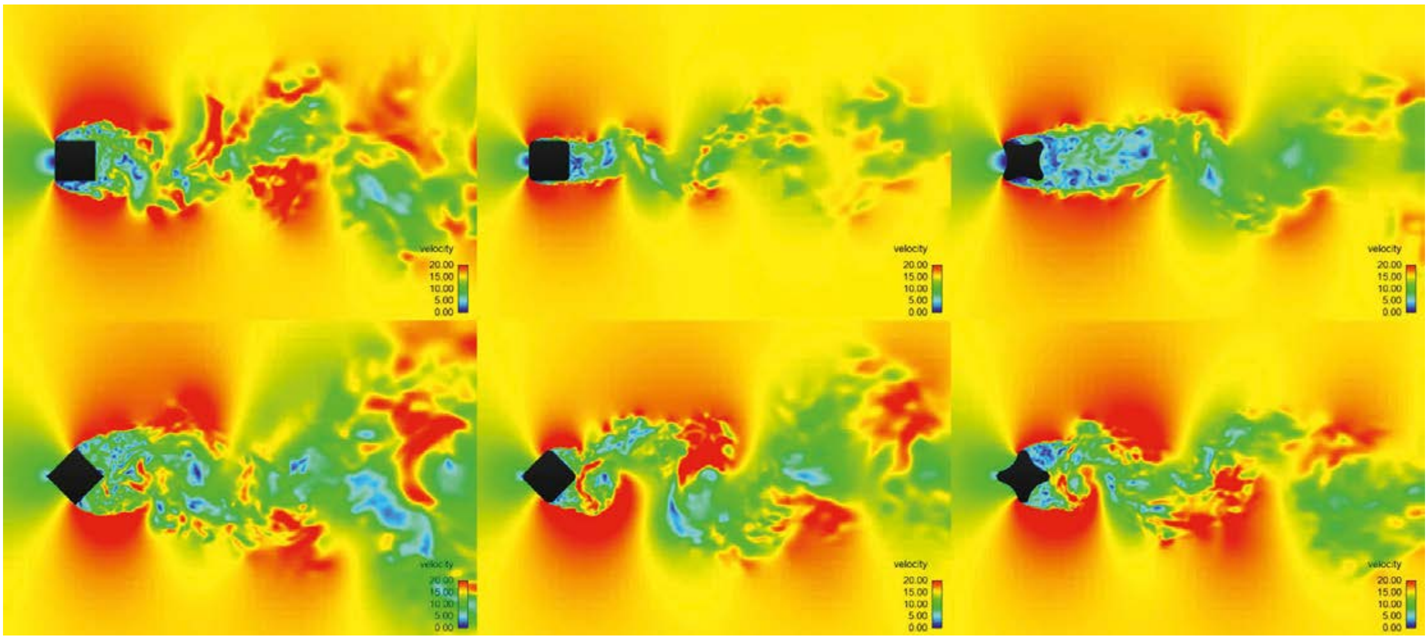
Steady and unsteady CFD simulations provided CO2 emission reductions and economy improvements for Eddie Stobart, and over 400 of its trucks now sport WR's aero kits



Architecture has been a successful new field for WR. The Foster & Partners-designed 300 metre tall National Bank of Kuwait (NBK) Tower was the subject of CFD simulations



Studying various tall cylinder shapes helped refine the CFD methodology for architectural flow simulations – it's pretty much impossible to do work such as this in a wind tunnel

kit was developed in CFD, independent correlations were done at MIRA and a 14 per cent drag reduction was achieved, leading to a theoretical seven per cent fuel consumption reduction at the regulation maximum 56mph (90kph): 'At which speed aerodynamic drag is roughly half of total drag,' says Rowsell. The kit was then refined to the most economic to manufacture parts, correlated independently again at Millbrook test track and 20 kits were made and fitted to trucks. 500,000kms later a three per cent real fuel saving was achieved and 400 further kits were then made.

Two different CFD solvers were used during this work; using the '2010 LMP recipe', RANS, or Reynolds Average Navier Stokes steady state solutions were run, and these were compared to DES, or Detached Eddy Simulations. The former is the more widely used method in most CFD solvers, such as ANSYS CFD and OpenFOAM. The latter 'unsteady' solver method is much more hardware intensive than RANS methods, yet for capturing the nuances of inherently unsteady phenomena such as vortex generation around a body like a truck could be more applicable.

At around the same time WR also began working in another entirely new field: architecture. In a pilot project with world-renowned architect Foster and Partners, WR carried out an academic study on vertical cylinders and on a Commonwealth Advisory Aeronautical Council (CAARC) standard tall building to tune the CFD parameters and, like the commercial vehicle work, this also helped to advance WR's understanding of unsteady flow prediction.

The architectural work focussed primarily on pedestrian 'comfort' near buildings and it's an aspect where CFD is taking over from wind tunnel work. One obvious, basic reason for supplanting wind tunnels is the ability to simulate the correct scale to achieve equivalent Reynolds numbers and, hence, 'flow similarity' in CFD, something which is impossible with scale models of buildings.

The first major project to come in for the WR CFD treatment was the Foster & Partners-designed, 300-metre tall NBK Tower in Kuwait. A practical wind tunnel model of such a body would be two orders of magnitude too small on Reynolds number. It was natural that these improved abilities to simulate unsteady flows were then brought to bear in motorsport simulations.

Improved vortex definition was obtained on the 2012 IndyCar model, for example, but there were costs in terms of resource requirements, and there were also some correlation issues as different development routes were followed.

One method of refinement that was used to accelerate small feature development on front and rear wings for the 2014 road course IndyCar was the adoption of sub-models. The model for developing the front wing comprised the front wing, the front wheels, the wheel internals, and a reduced detail rear body; the rear wing sub model was just that, the wing elements, end plates and mounting plates. The results were

WR applied the energy efficiency tools it had developed in motorsport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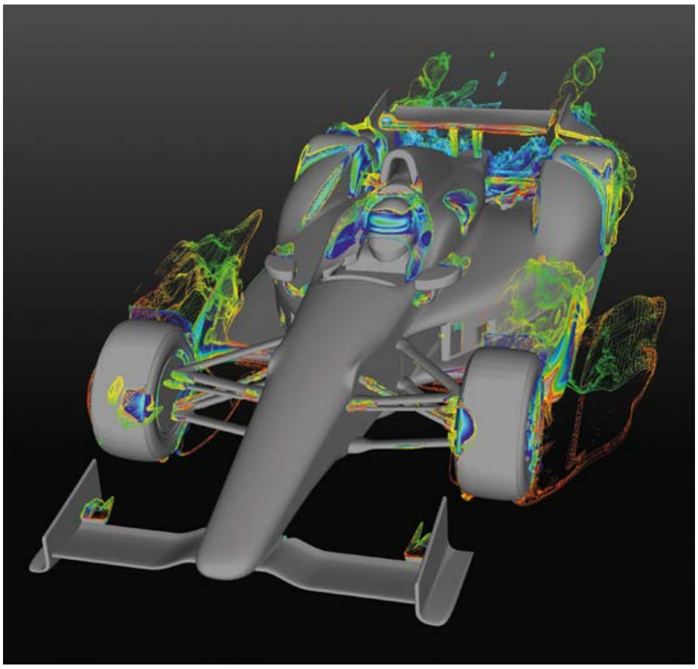
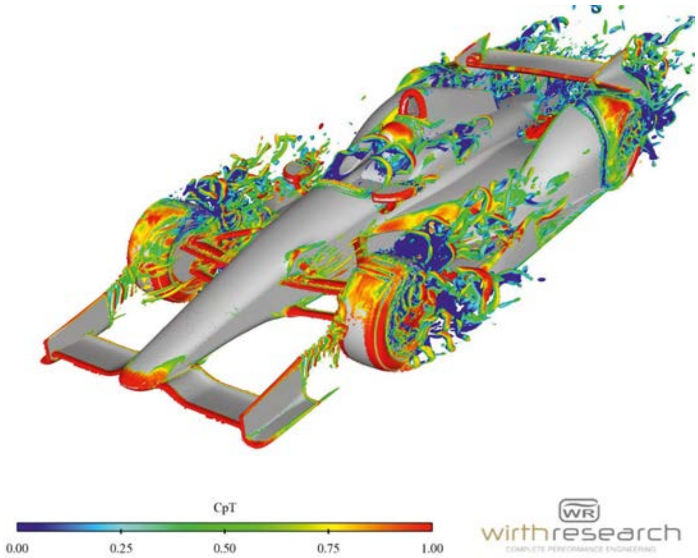
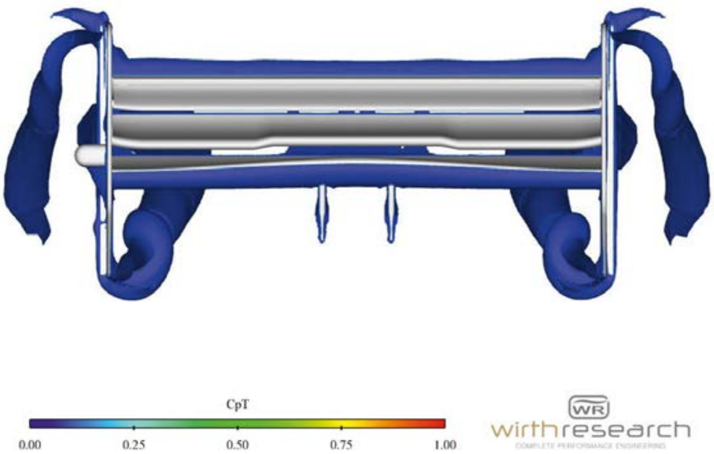
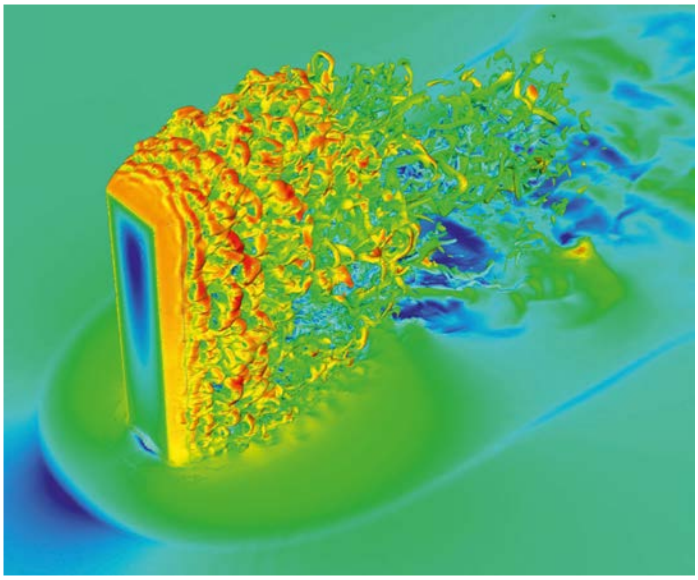




Left and above: Unsteady flow methods that were honed with WR's work on tall buildings helped to improve the vortex simulation on the 2012 IndyCar model



Productivity was increased with the use of sub-models; such as this rear wing with end plate assembly and mounting plates. The results correlated closely with full car models



Further simulations in architectural projects (above) helped develop methods now being applied in motorsport. These saw use in the development of the HPD LMP2 cars in 2016

said to correlate closely with the full car models, within limits, but the approach was to significantly increase productivity.

In 2015 WR examined EXA Corporation's PowerFLOW solver. This CFD code uses the so-called Lattice Boltzmann-based physics and differs from RANS solvers (which solve the conservation equations of mass, momentum, and energy in a viscous fluid) by treating the fluid as consisting of imaginary particles, and simulating the flow as a Newtonian fluid in which particle collisions propagate throughout. Its adherents point to its inherently transient nature and claim greater accuracy. However, WR's evaluations showed a large jump in hardware resource requirements; where unsteady DES simulations were 10 to 15 times more resource-intensive than RANS simulations, the Lattice-Boltzmann solver requirement was approximately double that again. Furthermore, in comparisons of the aero gains made on the ARX 04b over the 03b LMP2 car, the results of WR's normal techniques and the Lattice-Boltzmann solver were similar.

Building business

Further architectural simulations saw the seeding of rain into the airflow around buildings using Eulerian multi-phase methods with discrete particle modelling. And another civil engineering project looked at tall, variously shaped prismatic buildings that required the use of unsteady simulations, which helped further develop methodologies that are now being applied in motorsport simulations, and which have been used in the development of the HPD LMP2 cars in 2016.

Among other diverse recent projects were an involvement with the Ford Transit van of motorbike racer turned TV presenter Guy Martin, as he tackled the 2016 Nevada Challenge in the 150mph class; and UAV (drone) development with US and Japanese clients, which have seen low Reynolds number wing and propeller developments which have increased understanding of laminar flow transition prediction, that once again will have wider application.

Method development in CFD at Wirth Research has seen numerous examples of cross-sector knowledge transfer benefiting the speed and accuracy of simulation techniques available for motorsport applications. And, unlike Formula 1 teams, for example, being unfettered by regulatory restrictions on the resources it can utilise WR now says it has 50 per cent more processing capability than a Formula 1 team, if that team was to put all its aero development resources into CFD.

Where once, not so long ago, it was F1 that had the highest level of computational aero resources in motorsport, now, it seems, the independent providers that are the powerhouses of this particular branch of simulation technology.

Wirth now has 50 per cent more processing capability than an F1 team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Cast away

There's much more to casting high performance engine parts than simply pouring liquid metal into a mould – as *Racecar* discovered on a visit to Formula 1 supplier Grainger and Worrall

By GEMMA HATTON

Two different types of sand are used to manufacture the sand cores and the moulds of the casting. The regular sand has grains of 0.2mm thickness but for the more complex and intricate shapes a finer, partly synthetic, sand with grains of just 0.1mm is used in a hot curing process, so that the printed layers of sand are more compact and therefore stronger

In a Formula 1 engine during the combustion process the instantaneous gas temperature reaches 2600degC, which is half as hot as the sun's surface, and the gas pressure forces are equivalent to four elephants acting on each of the pistons. Within a blink of an eye an F1 engine completes 200 ignitions, with 43 trillion calculations over a race distance. And it only takes one combustion error in 37 million to cause a terminal failure.

With these figures in mind we can maybe start to appreciate the phenomenal challenge facing motorsport engine manufacturers. 'The shift towards small capacity turbocharged engines that we've seen in F1 and, are starting to see in other championships, results in the engine stresses and temperatures reaching new levels,' explains Phil Ward, director of performance products at Grainger and Worrall, which is a world leader in manufacturing structural engine castings. 'The increase in temperature is more of a challenge than the increase in stress, because the aluminium alloys within the engine experience a dramatic drop off in strength once a threshold temperature has been exceeded. A material that is perfectly strong at 160 to 180degC will behave like toffee above 250degC, so the alloys we used in the V8 era, which was only three years ago, are now no longer strong enough.'

This is one factor that has driven Grainger and Worrall to develop new casting processes, new material chemistries and new tooling. 'An additional consequence of these high engine running temperatures are the demands on the cooling circuits,' Ward adds. 'In previous engine generations the water jackets, for example, had relatively simple internal shapes, now their complexity means it's almost impossible to use traditional tooling methods without compromising the design. However, with our sand printing capabilities

Once the sand cores have been printed they are assembled into the final mould. Coolers and feeders are made to help control rate of solidification so that the tightest micro-structures are formed for high strength

'We use sand printing because it gives us an almost infinite capability to derive shape and size, with minimal constraints'

we have more freedom to achieve this required complexity because we can effectively print these shapes as a single piece.'

Every championship that races bespoke engines, including the likes of F1, LMP1, LMP2, WRC, WRX and Moto GP, utilise Grainger and Worrall cast parts such as cylinder heads and engine blocks, as well as transmission and gearbox housings. The technology at the heart of Grainger and Worrall is sand printing, which is used in over 75 per cent of its motorsport products. It allows the manufacture of intricate and complex shapes within a part which cannot be achieved through machining.

'We use sand printing because it gives us an almost infinite capability to derive shape and size, with minimal constraints,' says Keith Denholm, engineering and technology director at Grainger and Worrall. 'It's also a relatively low investment cost process so we can very quickly go from a drawing to a product because we don't need to make steel tools or buy large machines. Both motorsport and automotive are adding levels of complexity in terms of the shapes, physical and mechanical performance, and sand printing does a particularly good job of allowing us to optimise that.'

Sand printing

Essentially, sand printing is where a layer of sand, 0.25mm thick, is printed onto a 'jobbox', followed by a layer of chemical binder and then a further layer of sand. In this way, complex 3D shapes can be gradually generated, slice by slice. This type of rapid prototyping technology is used to manufacture 'cores' which are then secured within the moulds of a casting. Molten metal is poured into the cast and, once solidified, the sand cores are shaken out; leaving the desired and intricate holes and passageways inside the part. This process of casting with 3D printed sand cores may seem a relatively simple concept. However, every stage demands a detailed engineering and scientific approach to ensure the final product is of the highest quality to meet the high demands of motorsport.

Like all processes in modern engineering, the first step is to generate a 3D CAD model. As is the case with most components, this tends to be a battle between the designers who want their optimised shape and the manufacturers who want a design they can actually make. 'This is the first engagement we have with our customers and in most cases the customers desires lack manufacturing ability,' Denholm says. 'We then work simultaneously with them within the virtual world where we have the maximum opportunity to make changes with no time or cost implication. We also use simulations to analyse the casting process and how the moulds and the cores behave when in contact with liquid metal. The aim is to arrive at a product, in the shortest time possible, that meets their functional requirements and our manufacturing requirements.'

Design freedom

The capabilities of sand printing already offers advantages at this initial stage because it removes many physical constraints associated with traditional tooling, allowing more design freedom. 'We can now make the ship in the bottle, which we couldn't before,' Denholm says.

Once the design has been finalised in the virtual world, Grainger and Worrall engineers then have to think inside-out, because to manufacture a cast part you also have to manufacture the parts that aren't there, such as the voids. This is why the sand cores are used and they can be manufactured in two ways. The first is similar to building a sandcastle – a pattern is machined and filled with sand and the desired shape formed – or 3D sand printing is used.

'We have two printers that produce sand in a similar mechanical way, but have very different chemical systems,' Denholm says. 'The first is a cold curing process, where the binder fixes the layers of sand at ambient temperature, as they are printed. Therefore, once the part is finished, it is already glazed which makes it robust and

Main pic and above: sand printing has allowed the manufacture of the intricate shapes needed for modern race engines while maintaining the strength for the sand cores to survive 700degC of molten aluminium

suitable for large moulds. But for the more intricate cores we need a stiffer, more accurate sand, so we use a hot curing process. Here, the infrared lamp in the printer heats the layers of binder in between the sand to initiate the curing process and evaporate any moisture, before the parts are placed in a microwave for a final cure.'

Finer grains

The hot curing process enables the binder to retain its strength for longer by compacting the sand, which is essential for parts such as the cooling jackets which sit between two cylinder bores in an engine block. The sand core for a cooling jacket at its thinnest cross section is 1.8mm and with a grain of conventional sand at 0.2mm, only nine grains of sand will make up that cross section. Not only is this inherently weak, but the liquid metal could actually penetrate between these grains, resulting in a blockage. Therefore, a partly synthetic sand is used for the hot curing process, which has grains at 0.1mm to ensure that more grains are packed into these thinner cross sections. Essentially, the sand has to be strong enough to withstand the thermal loads of 700degC liquid metal during casting, but weak enough to shake out of the mould once the part has been cast.

'When in contact with the molten metal, the sand will want to expand by approximately one per cent, which is not dimensionally accurate,' says Denholm. 'This is why we not only have several types of sand with different chemistries, but also different curing mechanisms as well. With these two printers we can mix and match the sands and select what is appropriate in terms of time, feature and cost.'

Multi-tasking

Another advantage to sand printing is that many parts can be arranged on the same jobbox, as long as they are separated. Volumetrically, up to 80 per cent of the space is utilised, which can equate to six to eight pieces for an eight to 10 hour cycle on the hot curing printer, which hasn't been switched off for the last three months. The jobbox of the cold cure printer is 16 times larger than the hot cure printer and due to its size it is only used four times a week for 20-hour cycles, because it generates so many parts.

Unlike other additive manufacturing processes, sand printing does not require any supports to be printed to hold the piece together during printing. This is because the sand is so compact within the cured layers, it actually provides structure for itself. However, other structural features may be necessary to ensure the cores are held together and assembled in the correct positions within the mould. You may wonder why several cores are used, as opposed to a single core. 'Technically, we can produce a monoblock of sand, which replaces several cores, but you would never do that from a manufacturing standpoint,'

'We can now make the ship in the bottle, which we couldn't before'


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The molten aluminium needs to avoid exposure to air as much as possible and this is why the flow of the metal in the mould is controlled through some very complex gating systems

Denholm says. 'Firstly, how can you be sure that everything is right and that all the powdered sand is removed? Also, when the metal is poured in, the air has to displace out, so we don't want it to be hermetically sealed. There are obvious benefits to a single core as the loads are more uniformly distributed as opposed to gluing an assembly together and it also reduces the variability in position. However, we might aim to make fewer cores, but never just one lump of sand as that's not the end goal.'

Mass flow rate

Once all the moulds and cores are in position, molten metal, usually aluminium alloy, is poured and the casting is born. However, this pouring process has the potential to significantly reduce the quality of the aluminium. Therefore, precisely engineered gating systems are used to manage the mass flow rate of the metal at every point as it fills the mould. This avoids any velocities exceeding a critical criteria which could induce turbulence, reducing quality.

'We also ensure that we fill a mould uphill. If you pour metal in from the top, the metal will cascade down from layer to layer and backfill, similar to a shower. The water coming out of a shower head has a much larger surface area exposed to air than if you were to fill the bath up through the plughole. The latter will expose the water to the area of the bath, roughly a square metre. If you drop that amount of water in through droplets in a shower, the combined surface area could be as large as a tennis court,' explains Denholm. 'Bear in mind that aluminium loves oxygen, and aluminium oxide is a ceramic which doesn't weld together with metal in a casting, so you end up with different materials distributed within the structure. As they are not connected, they cannot transfer thermal or mechanical stress, creating cracks which are the basis of fatigue, and fatigue is the biggest failure mode of aluminium parts in an engine. That is why we invest in technologies that limit the opportunity for aluminium to grab oxygen throughout the entire process.'

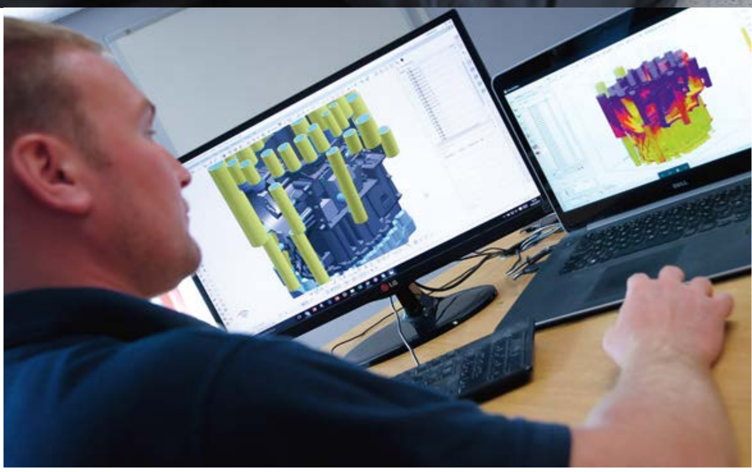
The next step is solidification. The rate and distribution of solidification can be manipulated to suit the performance requirements of specific areas of the casting. Theoretically, molten metal solidifies by transferring heat to its surroundings, which in most cases is the sand. If the sand was inert and thermally inactive, the metal would stay liquid forever. Naturally, the rate at which the heat conducts from the metal depends on the surrounding media. Therefore, areas of the casting can either be insulated to keep the metal liquid, or placed next to a heat sink, which has a high heat capacity (usually iron or steel) and conducts heat away quickly. This is how Grainger and Worrall can precisely control the growth of the crystalline structure as the metal transitions from liquid to solid.

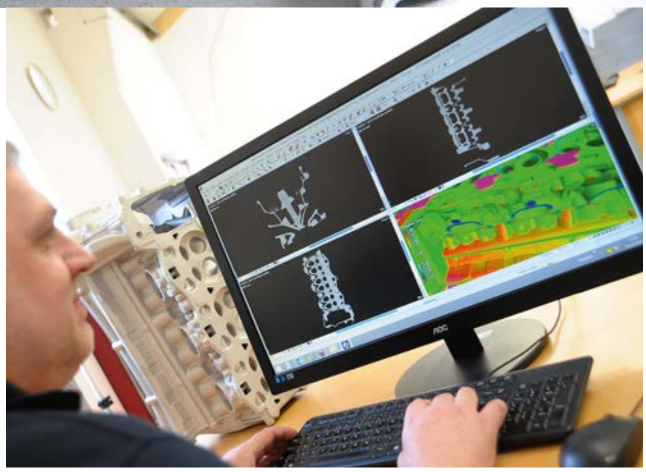
'Unfortunately, this process doesn't happen instantaneously, it's like the growth of a snowflake,' Denholm says. 'Take the gas face of a cylinder head where the explosion happens. This is typically an area where fatigue is most likely to occur and so we need to solidify that first to initiate a tighter microstructure with smaller grains. Therefore, we use coolers because the metal will have less time to grow before it solidifies. If you stop a snowflake from growing, it will remain small, which is why on cold snowy days the snow is more like frost, whereas on warmer days you get much bigger snowflakes.' This rapid solidification not only increases the inherent strength of the material, but also reduces the gas porosity within the structure because gas simply doesn't have time to escape during solidification.

As well as initialising solidification in particular areas, the aim is to also solidify the part in a consistent way. However, the varying

'Sometimes we deliberately manufacture parts not to be straight, because during solidification the part will straighten itself'

CarbonBlack
CarbonBlack





Detailed analysis on every cast product includes CT scanning, X-Ray and optical measurement. This allows G&W to quickly identify any defects within the casting, and their cause

thicknesses of areas of the part disrupts this uniformity, and so coolers are also used to mitigate this. 'We are always trying to solidify in a predictable way. Invariably, where we will channel the metal in at the bottom will remain the hottest point, but we also want feeders at the top to be liquid. Once the mould is full, coolers and insulators can be used to maintain the desired solidification pattern throughout the part,' says Denholm.

A further consideration is that after the metal has solidified it contracts volumetrically by approximately seven per cent, changing the size of the part significantly. To account for this, insulated tubes, or feeders, are placed on top of the mould and retain the aluminium in a liquid state for as long as possible to continuously fill the voids generated by this contraction. 'We've got this casting that wants to contract, but is restricted by the moulds and the cores,' Denholm says. 'So it starts to react to that and generate residual stress. We work very hard to reduce this stress but it's impossible to remove it completely. In fact, sometimes we deliberately manufacture parts not to be straight because we know that during solidification, the part will straighten itself.'

Scan analysis

Once the part is set, and the sand cores and moulds have been removed, the casting is taken through a journey of machining and heat treatments. This ensures that geometric tolerances for the in-cases of the bearings, for example, are in the order of 10 microns, which simply can't be achieved in the bulk casting

Then the analysis begins. The majority of the parts go straight into the CT scanner, where they sit on a turntable and a beam of X-rays is passed through the part and a line detector builds up an image of it in mm slices. This 20GB set of data is then imported into a software program which reconstructs the images using 250 million greyscales to determine the solid sections and ultimately generates a 3D model of the actual component. This is then overlaid with the initial CAD model sent by the customer and any areas of variation are highlighted.

'Casting is not a heterogenous process, so the part will always have slight differences in shape and size and the nature of solidification will cause defects,' Denholm explains. 'But we can do dimensional scanning to forensically verify the quality of our parts and determine the potential cause of defects.'

Grainger and Worrall also has optical scanning systems which analyse the surface

The majority of the components go straight into the CT scanner

Phil Ward (left) is director of performance products at G&W while Keith Denholm (right) is its engineering and technology director

The finished product. Grainger and Worrall has supplied parts to many high-end motorsport series and also works in automotive

measurements of parts and build up models, although this cannot 'see' the inside of the component. However, once calibrated, these optical scanners can use a pre-set program and analyse the quality of production volumes with no need for an operator.

'Usually, the first batch of parts are completely usable, but we may decide to implement minor adjustments of 0.5mm or 0.25mm to our tooling,' Ward says. 'By using our CT and optical scanners we can continue this iterative process so that by the second or third batch, the products have reached the fully adjusted condition. Ten years ago, to make a casting, it would take seven weeks to make the tool, then there was a long validation process of the first sample part and only then could you start manufacture. Now, we can receive a modified design from an F1 customer on a Thursday, use our printed sand processes to cast the parts, inspect them using our new CT technology within three hours, and supply race grade parts the following Tuesday. It's an extreme example, but it means our motorsport customers can introduce developments almost weekly, which is a radical step from the past.'

Quality control

The secret to achieving a high performance casting is to use the highest quality metal. However, this is impossible because every processing stage throughout the metal's life cycle reduces the quality of it, and introduces the potential of impurities.

'The very presence of an atmosphere causes all manner of issues for us when working with metals. The metal starts life as ingot and although it has already been processed many times, here it is potentially at its highest in terms of quality, but not perfect,' Denholm says. 'It's like any natural process in the world, you have this entropy effect where you go from a state of order to a state of less order. But we know that, so we have to ensure that at each stage we minimise that quality loss as much as possible.'

Monitoring variations

As mentioned previously, the biggest enemy is oxygen, and during the melting and pouring, where the metal is exposed to the most amount of air, it can form an oxide. Once in the mould, the issue then becomes the organic compounds within the fixers of the sand cores, which begin to decompose, generating gas. The metal needs to be kept as pure as possible, because any form of impurity, no matter how small, could lead to the beginnings of a fatigue failure when subjected to the extreme engine loads.

'Every day, things will be slightly different,' says Denholm. 'From the variations in ambient temperature to the amount of fixers in the cores, which means one day you can get a bad outcome and the next you can get a great outcome. With so many variables to control it is rare to actually increase the quality of the metal throughout its journey and therefore the only strategy is to minimise the quality loss at each stage. Perfection doesn't have a bi-lateral tolerance, you can either be perfect or not. If you set a standard of no defects, you can only ever go one way. That is why it is so essential to understand what is driving the variations within our processes. However, casting with sand printed technology has stood the test of time, because it works, and works really well for our applications.'

The metal needs to be kept as pure as possible, because any form of impurity could lead to the beginnings of a fatigue failure

Star cast

Grainger and Worrall's continuous drive for innovation and development has helped it win nine awards over the last five years. It has supplied parts to every F1 constructors' champion, and nearly every F1 race winner since the early 2000s, with its involvement in other series proving equally successful.

In the last 12 months alone, Grainger and Worrall estimates it has completed 400 turnkey products within the motorsport and prototype teams. 'These departments are effectively the heartbeat of our business, from which all other areas can benefit from. The fast-paced demands from motorsport forces us to try new things, evaluate and improve. This has helped us develop an innovation culture,' explains Denholm. 'The new technologies we are seeing are often first deployed in motorsport, which means we can become very early adopters of technology because we have a market to place it in. We don't have to wait for the next product cycle of a car manufacturer to jump on the bandwagon of the newest tech.'

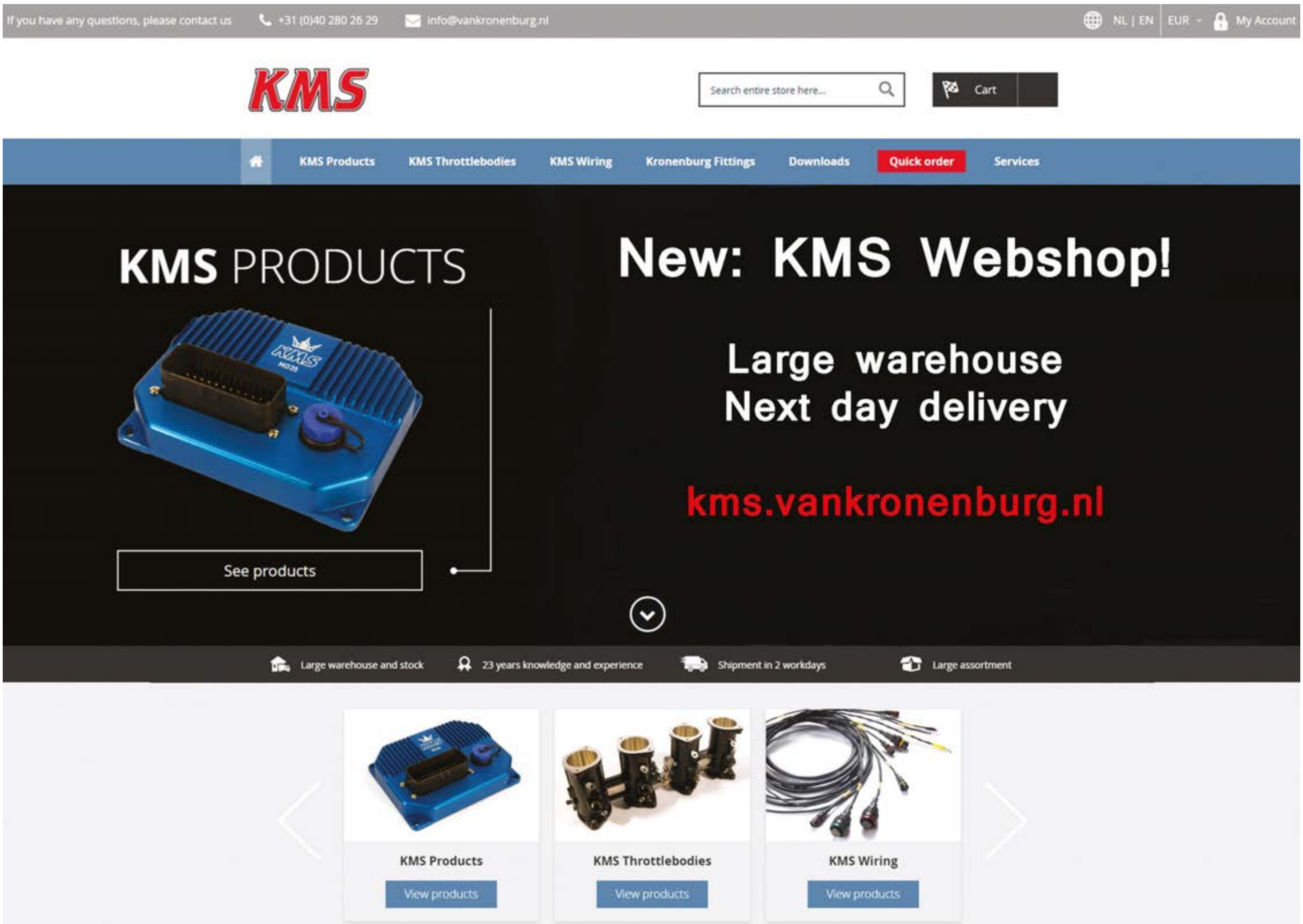
Ward adds: 'F1 is at the forefront of that drive for innovation, because they are the most stressed engines we supply. However, what works in F1, also works for other high-end series of racing. A cylinder head for an F1 engine doesn't look much different to a cylinder head from Moto GP, the differences are more subtle.'

Although high end racing demands obsessive attention to detail, supplying spec series comes with its own challenges, too. Not only do these championships want high performing products, but they also want impressive durability, reliability and they also need equality.

Print run

Sand printing technology is unique to Grainger and Worrall in motorsport and has been the key to its success. When purchased around four years ago, the sand printers were one of the first in the UK, and most likely Europe. 'Now there are arguably three or four companies across Europe who have the capability to produce the same level of product as we can, but in motorsport terms, no one is matching our technology on the scale that we are achieving,' Ward says.

'It is still open competition,' says Denholm. 'We have no right to be a dominant force in the industry, but we've had a head start and learnt our lessons. Every team sets out their business plan to win the championship, and putting their plans at risk with mediocre or late product is not an option. The option is you supply perfect product on the day, and in the quantity, that they want it.'



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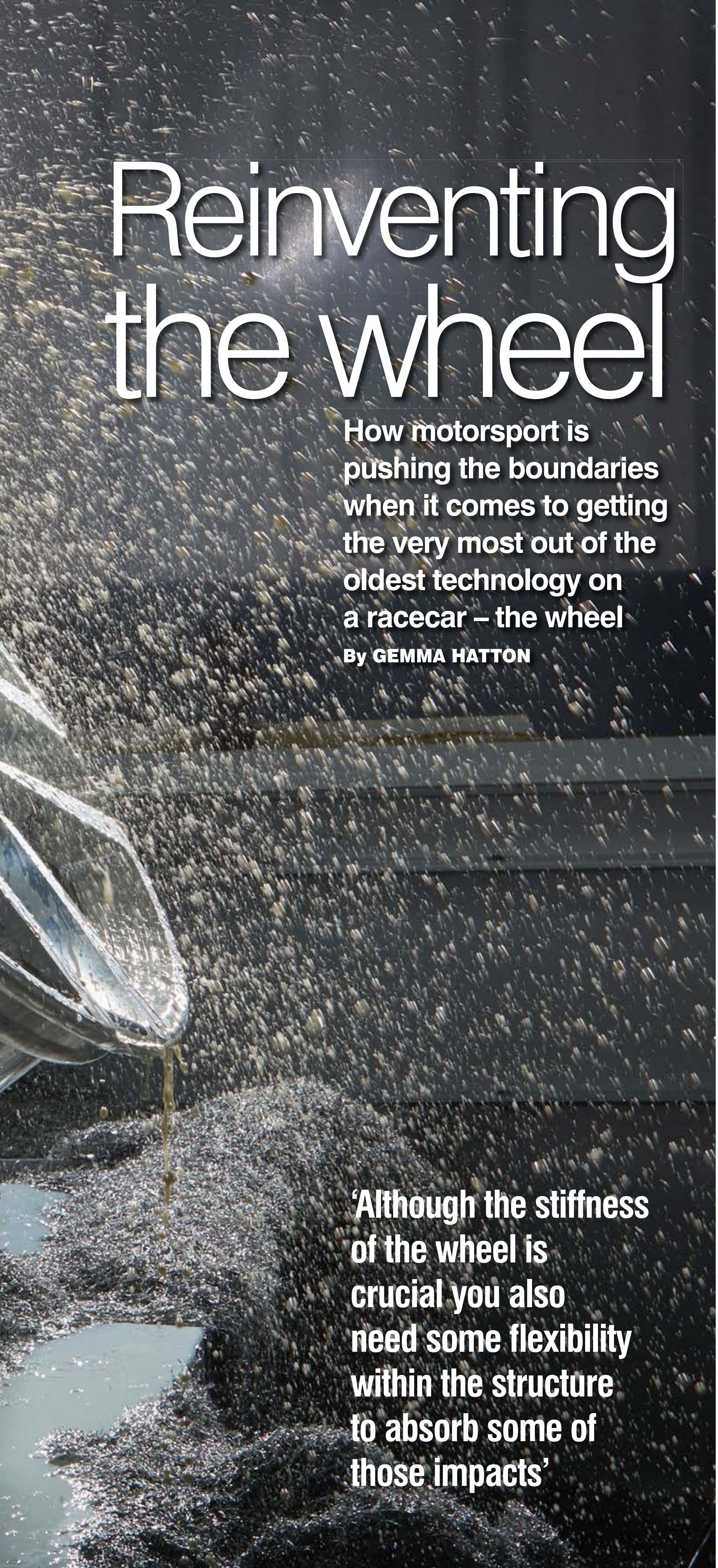
After casting or forging, rims are machined. Motorsport wheel design is a balance between having a light, yet strong enough, component



Reinventing the wheel

How motorsport is pushing the boundaries when it comes to getting the very most out of the oldest technology on a racecar – the wheel

By GEMMA HATTON

Tyres are a constant talking point in motorsport, but the wheels they are mounted on are rarely ever discussed. Teams and drivers dedicate a huge amount of time and resources into eking every last iota of performance out of the tyres, yet expect the wheels to be indestructible.

These wheels have to not only survive, but also perform under an enormous amount of loading; the torsion loads under braking and acceleration; the longitudinal and lateral tyre loads and the downforce, which in F1 can be as much as four times the weight of the car itself. This demands the wheels to be of the highest strength, yet when the wheels rotate an impressive 6138 times during one lap of Le Mans (based on this year's Kamui Kobayashi qualifying lap), minimising the inertia and the unsprung mass is essential; demanding that the wheels are also as light as possible.

Spokes man

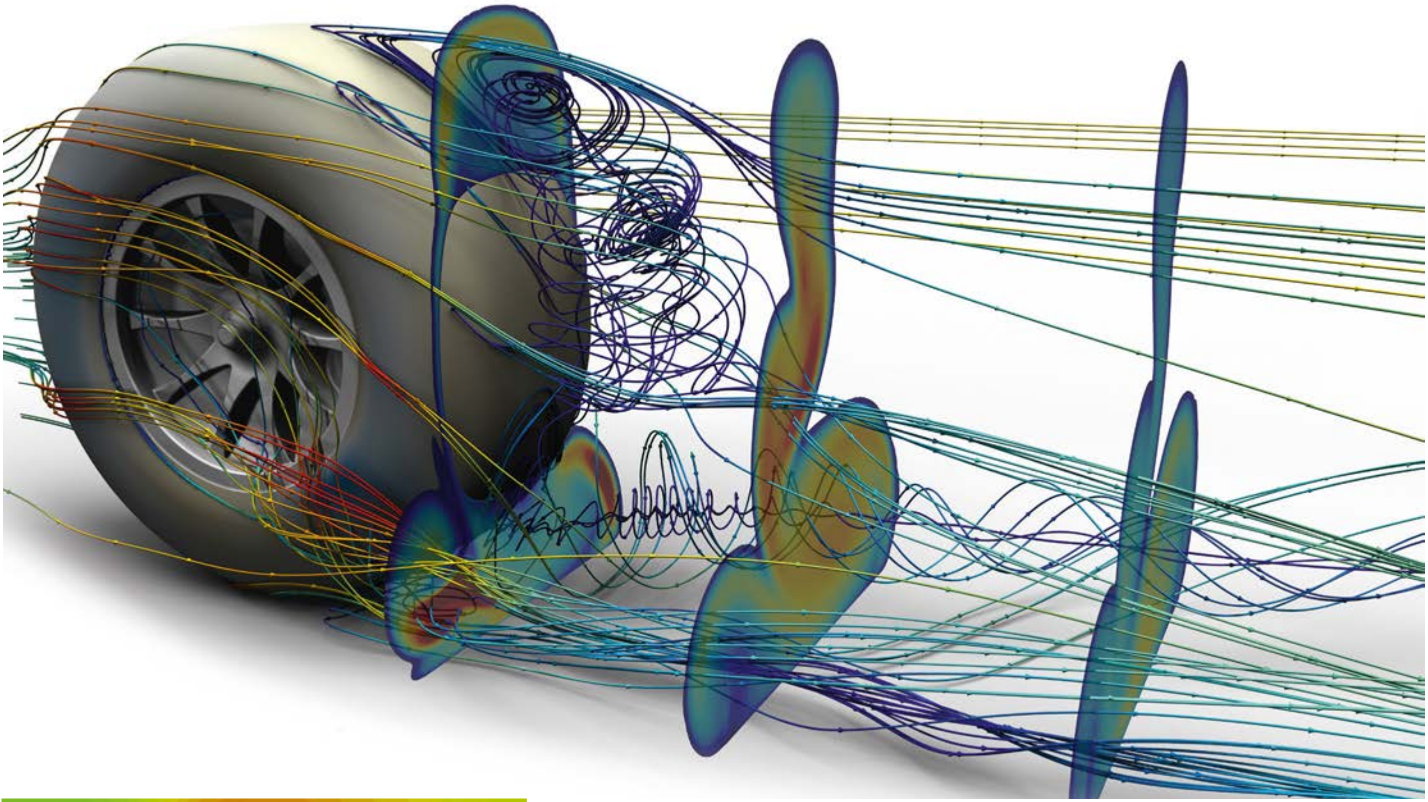
'The varieties of motorsport require different demands from the wheels. Formula cars are generally lighter, but have much higher downforce, whereas GT or touring cars can be twice the weight with a quarter of the downforce,' says Matt Neal, brand ambassador for Rimstock and three-time BTCC Champion. 'As drivers look for every inch of the track, there is also the issue of kerb strikes, which can impact the areas around the end of the spokes which are high stress points and critical to the integrity of the wheel. Therefore, although the stiffness of the wheel is crucial, you also need some flexibility within the structure to absorb some of those impacts.'

These race track impacts are nothing compared to the brutal conditions of rallying and rallycross, however, which have the added challenge of enduring continual shock and compression loadings. 'Wheels for circuit racing suffer much less abuse than those used in rallying,' says David Williams, director at Speedline Corse. 'For rally, we are not only dealing with general durability and fatigue, but also the impacts when the car lands after jumps. One of the main areas we also analyse is the much higher loads to the wheels from the tyres, because rally tyres have to be much stiffer to deal with the rougher terrain.'

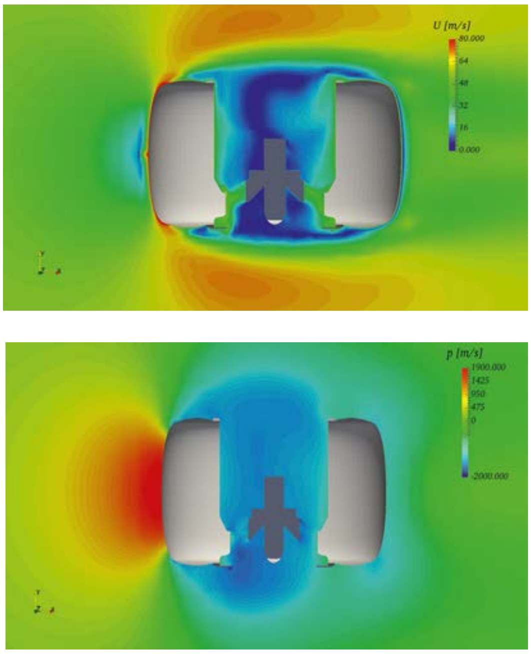
'Although the stiffness of the wheel is crucial you also need some flexibility within the structure to absorb some of those impacts'

Well and good

Similar to most components on a racecar, the regulations often dictate the fundamental dimensions of a wheel, along with the allowable processes and materials. The actual shape of the wheel, however, is determined by two characteristics; the well of the wheel and the rim profile. From a cross sectional view, the shape between the inside and outside rim often has a slight dip, or well, which is



The aero-effect of wheels is now better understood. Siemens conducted a simulation of the airflow around a 2016 F1 wheel. The streamlines and slices show the complex turbulences generated on a straight at 250kph



Simscale's CFD study of velocity distribution on a wheel (top); green area inside wheel shows cross-flow which generates drag. Bottom image is pressure; the large blue area is pressure drag

Forging is where high pressures and temperatures are used to press a blank of malleable material into the rough desired shape

continuous around the circumference of the wheel. The depth of this well dictates the size of the brakes which fit within the wheel and act on the hub. Therefore, motorsport wheels usually have a shallow well for clearance for larger brake discs and calipers, compared to the deeper wells found in road car wheels.

The profile of the rim is dictated by the size of the humps, which is where the bead of the tyre sits. In motorsport, the lower running pressures, particularly in rallying applications, require tall humps to ensure that the bead of the tyre cannot go over the rim and come off. However, if these humps are too tall then the pressure needed to mount the tyre over the rim and 'pop the bead' are extremely high, which is not only unsafe, but also subjects the wheel to severe shock loads.

Mounting tension

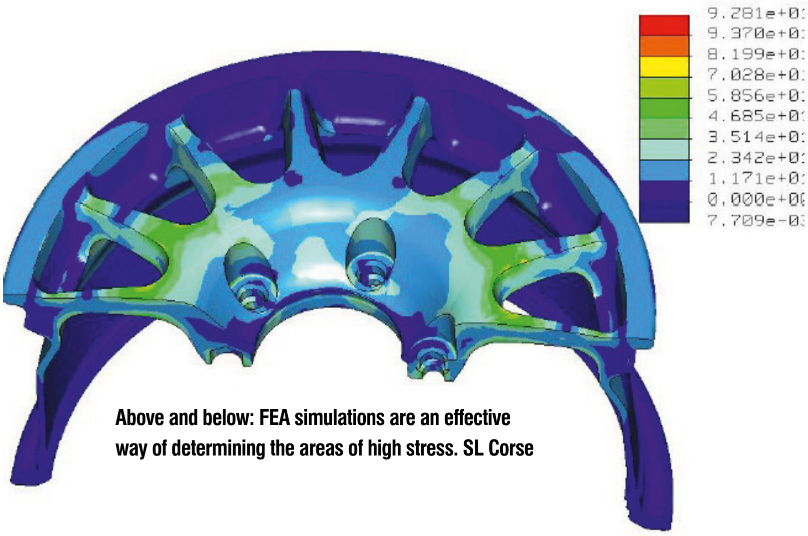
Williams says: 'Sometimes it can take up to 11bar to mount the tyre onto the wheel, which is not only extremely dangerous for the tyre fitters, but can also potentially damage the wheel structure. Therefore, the design of the humps is a compromise between having an aggressive enough profile to ensure the tyre simply can't come off, even at low running pressures, whilst being shallow enough to avoid extreme mounting pressures. Of course, you also need to consider the removal of the tyre as well.'

We all understand the benefit of lower tyre pressures; the reduced tyre stiffness at lower pressure increases the contact patch size under load and therefore increases overall grip. This is why drivers and teams will do anything and everything they can to run lower pressures. However, run too low and the tyre will come off the rim completely (as often seen in the latter stages of a slow puncture), which is one of the reasons why tyre suppliers in certain categories recommend minimum pressures. There is also the effect of temperature, where cool conditions result in lower pressures, increasing the risk of de-beading.

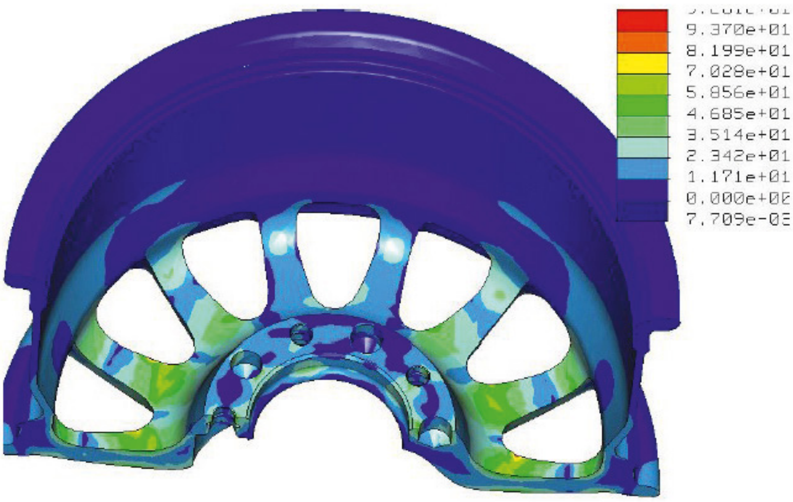
'From a rally point of view, teams will often start off with very low pressures, around 1.8bar, and expect them to rise to approximately 2 to 2.2bar when the tyres are warm. It has been known for teams to run even lower, but of course that increases the danger of the tyre coming off the rim before it's up to full pressure,' explains Williams. 'To address this balance of avoiding de-beading whilst achieving safe mounting, the FIA introduced a maximum mounting pressure into both rally and rallycross championships. To achieve this we have also worked together with the tyre manufacturers to try and reduce the stiffness of the bead to minimise the mounting pressures.'

Wheel right

There is not one optimum approach for the manufacture of motorsport wheels, both in terms of material and process. High end racing such as F1, LMP1 and GT use forged magnesium wheels, whereas the lower tiers of motorsport, often requiring higher volumes, usually use cast or forged aluminium.



Above and below: FEA simulations are an effective way of determining the areas of high stress. SL Corse



The Toyota LMP1 wheels have been developed by Rays and over the last three and a half years have gone through over 30 iterations. This year's features the widest fairing yet, which is designed to aid the attachment of the airflow around the wheel

Forging is generally considered to produce the lightest wheels. This is where high pressures and temperatures are used to press a blank of malleable material into the rough desired shape. The rim section is then forged whilst the blank is spinning and, once complete, the finished forge is then machined to achieve the high quality of the final product. This process of deformation eliminates the potential for porosity and also modifies the grain structure from non-directional to multi-directional, which provides high strength and integrity.

As a consequence, less material is needed within the wheel to achieve the same levels of stiffness and so it can be made lighter. However, this reduction in weight comes at a premium as forged wheels can be as much as four times more expensive than cast wheels, which is why cast wheels remain popular in the lower categories of motor racing.

Rays of light

'For the Toyota TS050 LMP1, we use our Design Forging Technology to produce one-piece magnesium wheels,' says KJ Yamaguchi, director of Rays. 'The advantages of this process is to mainly keep the metal flow to the very end of the rim, without having to cut into the middle, which retains the rigidity, and also to raise the forged ratio.' The forged ratio is the ratio between the original cross section of the blank and the cross section of the final product after it has been drawn out.

There are two main types of casting technologies used to manufacture wheels worldwide: gravity casting and low pressure casting, with the latter widely used in motorsport. 'For low pressure casting, we're essentially injecting a measured amount of molten aluminium alloy into the mould, a vacuum is created which helps fill the mould effectively,' says Williams. 'The mould then has to be cooled and to accelerate this solidification process we use a mixture of water and air-cooling in and around the moulds. This helps us to achieve the desired cooling rates to generate consistent grain structures whilst ensuring the material is homogenous.'

Rim of fire

Controlling the rate of solidification is essential to ensuring the tighter microstructures develop in the areas requiring enhanced strength (see Grainger and Worrall feature on page 62 for more on this). However, with wheels the target is to achieve consistent solidification throughout the part, and this can be disrupted by the thicker sections of the wheel, which

Flow forming

One other manufacturing technique that accomplishes the compromise between developing wheels that are both light and strong is the patented flow forming technology from Speedline Corse. As normal, the wheel is cast, but usually narrower than the conventional shape, despite using the same amount of alloy. The casting, which is approximately 400degC at this point, is then placed into a secondary mould which is spun at high rpm and the malleable metal is formed into the desired shape of the final wheel.

'Essentially, flow forming is a way of taking a cast component, and turning it into a finished component by spinning and squeezing it in a secondary mould. Similar to a potter's wheel, where the clay is drawn out and forms the final shape,' says Williams. 'We use this technology for many of our circuit racing wheels and all our tarmac rally and rallycross wheels. This process not only gives a tighter grain structure within the casting, but also aligns all the grains in a uniform direction. This increases the strength, which gives us the flexibility to reduce the thickness of the rim and therefore make lighter wheels.'

Process of drawing out the malleable metal whilst the casting is spinning at high rpm aligns the grains in a single direction

'For rallying we are not only dealing with general durability and fatigue, but also the impacts when the car lands after jumps'

Touring car wheels need to be strong enough to cope with cars twice the weight of single seaters, while they will often get a bit more abuse too. Kerb strikes can impact the high stress areas around the end of the spokes

is why these complex air- and water-cooling systems have been developed to mitigate this. Once cast, the wheel will then go through a series of heat treatments such as annealing and finishing processes before detailed analysis of the quality of the part using X-ray or optical scanning techniques.

'Designing a lightweight wheel is very easy, but designing one that is strong enough and that can survive the tough environment of motorsport is a lot harder,' Williams says. 'Often, the FIA have mandated a minimum weight for the wheels which is our starting point. We can then use processes such as our Flow Forming Technology (see box out, left) to reduce the section thicknesses of the part. Fundamentally, the less aluminium in the final product, the less it will weigh.'

Aero issues

It's not just about weight and strength, though. There are aerodynamic effects to be considered, too. The design of the wheel spokes and the overall 'face' of the wheel play a major role in dictating the airflow around the wheel, which can be an area of high drag, particularly in open wheeled formula cars. From an aerodynamic point of view, the most efficient design is to have the wheel as a flat face to keep the airflow attached. This was showcased in the Mercedes Benz IAA concept car, where the gaps between the spokes are completely covered. In fact, above certain speeds, the wheel actually deforms, so the centre hub of the wheel bulges outwards, creating a flat surface so the airflow can stay attached along the entire side of the car. Unfortunately, these designs are almost impossible to achieve in motorsport, as the larger brakes restrict the possibilities, as they dictate the wheel size.

'There are a number of vortices that are generated around the tyre,' says Dr Christopher Beves, from Siemens PLM Software, which created the STAR-CCM+ CFD software many F1 teams use. 'There are two big vortices that form at the side of the tyre contact patch and some smaller ones from the wheel rim. The flow separates over the top of the tyre, where most of the wake behind the tyre comes from. There is another horseshoe-like vortex behind the tyre, and being able to manage and direct all of these vortices along the car will ideally improve performance. Of course, this is only in the straight line condition, during cornering when the sidewall of the tyre is flexing, these flow features change and analysing a properly loaded tyre mid corner is challenging.'

Tyre deformation

The aerodynamics around the contact patch constantly evolve depending on the vehicle dynamics. The way the tyre bulges when travelling in a straight line will change when the sidewall flexes under a change of direction due to cornering. This will alter the way the main tyre contact patch vortices behave downstream. 'The stiffness of the sidewall is another major concern, which is why teams no longer consider the tyre as a perfectly solid cylinder in their simulations,' Beves says. 'Pneumatic tyres are now increasingly used in wind tunnel testing to try and replicate the tyre deformation realistically as well as morphed boundaries in CFD simulations.'

One interesting wheel design is that found on this year's LMP1 cars. Both Porsche and Toyota developed wheels with a wide fairing, which is essentially a band joining the ends of the spokes to the rims, but all as one piece. Similar to the Mercedes Benz IAA Concept, the area of gaps between the spokes is reduced, and therefore minimises the risk of flow separation. Toyota's design has evolved over the years, with this year's version featuring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‘The problem with carbon is that when it fails it can be catastrophic because it’s a complete disintegration of the wheel’

the widest fairing yet. ‘We figured that this fairing is highly effective for the airflow around the wheel and tyre, however, the width of this fairing is restricted by the regulations,’ Yamaguchi explains. ‘We have modified this design more than 30 times over the last three and a half years and found that slight changes in the shape can affect lap time by 0.003 to 0.005 seconds.’

As for the future of wheels in motorsport, what about carbon? Carbon fibre wheels are no new concept, but currently there is only one company (Carbon Revolution in Australia) in the world with a genuinely industrialised process to manufacture one-piece carbon fibre wheels. But this is essentially a plastic technology, and designing to meet all the demands of a motorsport wheel when you have multiple layers of material is very difficult – the possibilities of getting the right properties in the right directions are almost infinite.

‘The problem with carbon is that when it fails it can be catastrophic because it’s a complete disintegration of the wheel, rather than simply bending,’ says Neal. ‘Carbon also ages with time, it’s similar to the rubber used in tyres in that respect. We’ve been working with a few manufacturers to use carbon in the rims and centres of aluminium wheels, but it’s not the perfect engineering solution.’

Rays has found that slight modifications to the fairing on its wheels have led to small but very real lap time gains for Toyota

Revolutions

But the future electrification of both motorsport and automotive is perhaps a further reason for developing carbon fibre wheels. ‘We believe it is inevitable, especially for electric cars where minimising weight is critical. We’re all going back to Colin Chapman’s idea of engineering lightness,’ Williams says. ‘Lighter wheels also reduce inertia, so not only can the wheels spin up faster, but it takes less energy to do so. Therefore, energy can be conserved, which is the fundamental principle of electric vehicles.’


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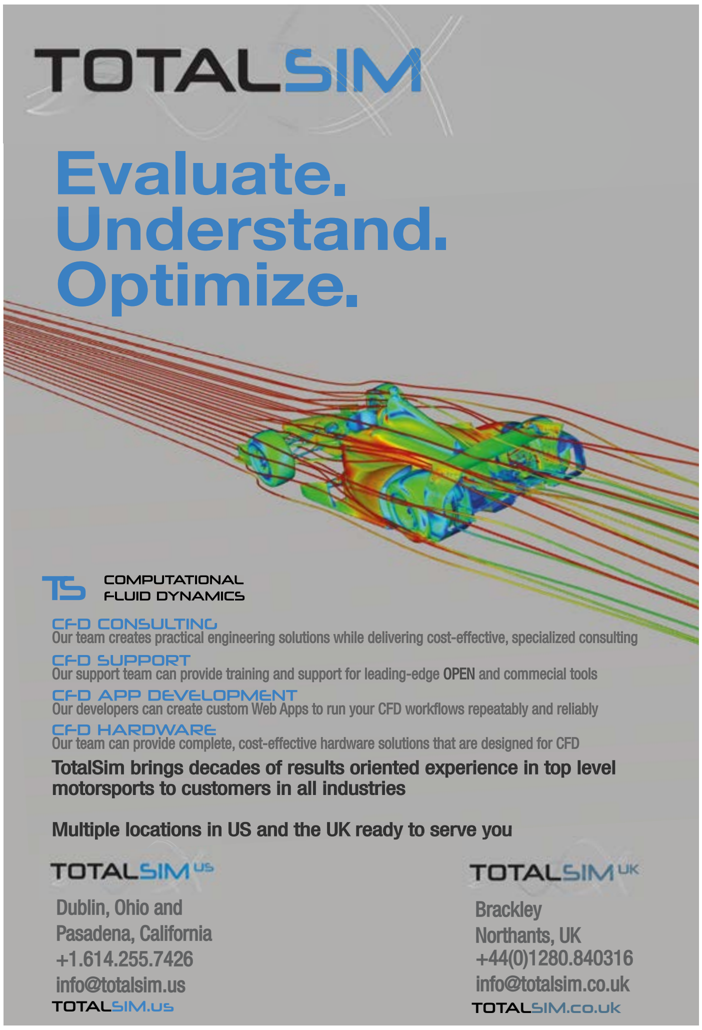
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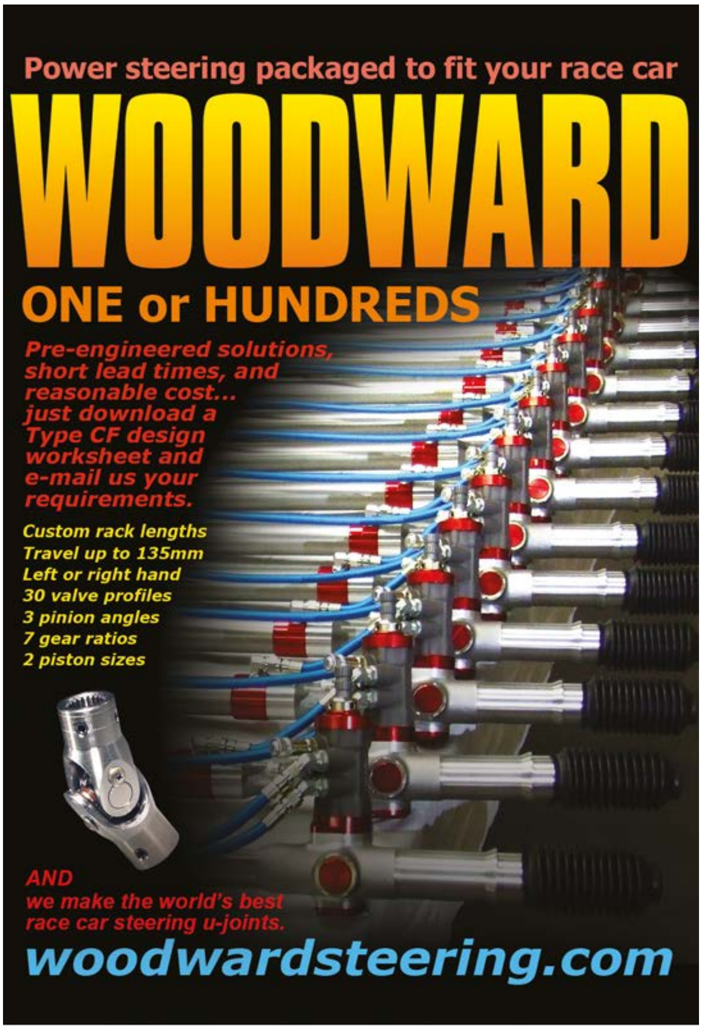
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Agents **of Shield**

The latest F1 cockpit protection device was aired in practice at the British GP – but a disappointing test, and lack of time, has now resulted in a decision to go with the Halo in 2018

By SAM COLLINS

Before the British Grand Prix, the latest in a line of experimental cockpit safety systems was trialled on a Ferrari SF70H during free practice. Dubbed the Shield, the device is designed to protect a driver's head from flying debris, such as that which killed Henry Surtees in F2 in 2009 and Justin Wilson in IndyCar in 2015.

The new device was developed following the mixed response to the steel Halo device trialled in 2016, and also the Aeroscreen tested by Red Bull. Early this year it was announced that a cockpit protection system would definitely be introduced for the 2018 season and for a while Shield looked like the best solution. But, since the test, F1 has now opted for Halo.

Shield revealed

Silverstone was the first chance for most of the paddock, the media and indeed the public to see the Shield, which when revealed did not look nearly as sleek as the concept renderings circulated when it was announced. However, the design did seem to get a generally positive response in terms of its aesthetics.

Made up of an as yet undisclosed polymeric material from the polycarbonate family, the prototype weighed in at around 4kg, with another 2kg for its mounting plate. Four variants of the Shield have been developed, two different shapes with two different thicknesses available for each. The version used at its Silverstone test was the thinner of the two, the thicker version weighs an additional 2kg.

Dizzy spell

One of the reasons for the two different thicknesses was that the Shield had yet to be subjected to all of the impact tests, which have previously involved a complete 20kg wheel and tyre assembly being fired at the cockpit protection device at 225kph.

The design of the Shield immediately raised concerns over its impact on driver visibility during a race, with reflections, the build up of dirt and indeed water during wet conditions a factor. Understanding some of these issues was part of the reason for the short test at Silverstone. But it must be said that the test could not be deemed a success. Sebastian Vettel, the driver who tried it out on track, actually cut the run short as he disliked it so much. 'We had more runs planned with it, but I didn't like it so we took it off. I got a bit dizzy and forward vision is not very good. I think it's because of the curvature, you get quite a bit of distortion, plus you get quite a bit of downwash down the straights, pushing the helmet forwards,' he said.

Wind Shield

The design would clearly have an impact on the overall aerodynamics of the car, but according to one team engineer the effect 'is not huge, it does not seem to have a big hit on the rear wing, but of the two shapes we found that both

Questions were raised about driver egress from the tight cockpit opening created by the sloping sides of the Shield. Two different shaped versions of the device have been produced

Vettel ran with the Shield fitted in FP1 at Silverstone. He was not impressed, criticising the reduced vision and the aero downwash

The Formula 1 Strategy Group has now made a decision to introduce the Halo device to F1 in 2018, despite it being hugely unpopular with fans. There are challenges with fitting it to the cars to overcome first, though

had an impact on the airbox; one shape was a bit of a positive impact, the other had a bit of a negative impact, so we will need to work around that once we know what shape we will get. There is a small overall drag reduction too.'

Visual distortion caused by the relatively tight curvature seems a hard challenge to overcome, it is less of an issue in Le Mans Prototypes, for example, as the screens are not as curved, while in fighter aircraft (such as the F16) reference points are much further away so the effect of the distortion is lessened.

Another issue which has been raised is driver extrication, not just in an accident but in normal circumstances. The design effectively raises the height of the side of the cockpit making it much harder for a driver to get out. Indeed, former Formula 1 driver and television pundit Martin Brundle, watching the Ferrari driver climbing out of the car, pointed out that should he stumble at the wrong moment he may well find himself in quite considerable pain if he were to land with his legs either side of the narrow upper edge of the Shield.

'I got a bit dizzy and forward vision is not very good. I think it's because of the curvature'

Vettel did not comment on that exact point, while he down played the extrication issue, too: 'It doesn't help getting out of the car, but that is probably getting used to it more than anything,' he said.

Time's up

One of the reasons that there were two different shapes of Shield in development, and that neither looked exactly like the renderings, is that time was too short to change the design of the 2018 monocoques to accommodate it as originally envisaged. As the teams are currently close to finalising the 2018 monocoque designs, and even starting the manufacturing process, it was not possible for them to do use the somewhat sleeker concept and instead a more upright version was created.

'It helped a bit that we knew that it will be a single spec component supplied by the FIA to all of us, so that would have helped us define things a lot. We wouldn't have needed to experiment ourselves with shapes and getting it through tests and things,' explained one Formula 1 team's chassis designer.

'The problem we had was that there was just no time,' he added. 'We needed to know the details before the summer break, otherwise it was just too late.' Further testing of the Shield had been planned at both the Hungarian Grand Prix and at the Italian Grand Prix in September. However, ultimately, the Formula 1 Strategy Group decided that the time was too tight to implement the Shield for 2018, so as a result the unloved Halo device will now be employed, though that has some very different mounting point challenges which will still need to be defined in the technical regulations.

Weight implications

The varying weights of the Halo (over 15kg) and Shield (6 to 10kg) would have also have had an impact on the overall layout of the car in terms of centre of gravity height and overall weight distribution. In Formula 1 there is only a very small window allowed for weight distribution and the introduction of the cockpit protection system will require other components to be moved. So, while the Halo decision is far from popular, Formula 1 teams will be relived a decision has at least been taken.

But not everyone believes that any additional cockpit protection system is required at all and perhaps the most outspoken critic of them all is, ironically enough, one of the drivers these devices have been designed to protect: Romain Grosjean. 'I've made myself clear since the beginning: we don't need anything, I'm against every Halo or Shield or whatever, it's not F1,' he says. 'This is as bad as the Halo. I tried the Halo last year, I hated it, it made me sick, so we haven't yet found a good solution.'

The toughest test

Why a tyre company's involvement in racing will have more to do with sticky rubber than stickers on a racecar

Falken has long used the Nurburgring 24 Hours as a testing ground for its race rubber and it sees this as a useful development tool for road car tyres

The 2016 Formula 1 season saw Pirelli supply a total of 42,792 tyres, of which only 37 per cent made it out of the garage. Like most tyre manufacturers, all available sets are fitted at the track and then given to the teams. Every tyre is tracked with bar codes, every puncture is bagged, and every chunk of rubber is collected after a session.

But why would a tyre manufacturer conduct this almost military operation to supply just a few racecars? Answer: motorsport tyres showcase each manufacturer's latest advances in tyre technology, and the concepts raced today could be driven on the road in the future.

Supplying tyres to a motorsport team or championship is no longer about commercial advertising and peppering racecars in stickers. Motorsport provides a realistic platform to rigorously test the latest concepts in a wide range of extreme conditions and under the harshest circumstances. Once the technology is given the thumbs up from motorsport, it develops into the road car tyres we drive every day. This is why we are seeing automotive trends of safety, longevity and reliability continuously reflected in racing. For example, the ACO initiated a new rule for Le Mans, where teams could refuel without having to complete a tyre change. By also reducing the number of mechanics, suddenly a new set of boots cost an extra 25 seconds compared to a refuel stop. Teams were quickly demanding a tyre that could withstand two to four stints at Le Mans, pushing Michelin to improve the durability of its tyres – a road car must. Even F1 is now starting to focus on harder compounds with less degradation.

Compound interest

It takes around 200 raw materials to manufacture a tyre, leading to countless compound and construction combinations. This is another attraction of motorsport; the rapid rate of development allows continuous experimentation. During the last F1 tyre war in the early 2000s, competition was so intense that manufacturers had to react quickly and develop new tyre designs to suit specific circuits. This resulted in each manufacturer generating an impressive 30 different compounds per season, compared to the seven we had in 2016.

'There is simply no better proving ground for designing tyres than real world competition,' says Peter Dumbreck, Falken's longest serving race driver. 'Our tyre engineers can acquire so much more information across a diverse range of weathers and surfaces at an event like the Nurburgring 24-hours than would be possible in the lab. It's such a unique place.'

Rubber 'Ring

The above is a conclusion shared with many automotive and motorsport manufacturers, who treat the Nurburgring as the world's ultimate proving ground. The 25km long circuit incorporates 170 corners and a 300m elevation change, all situated within a unique microclimate. This caused carnage in the 2016 Nurburgring 24-hours race, when a hailstorm in the north section brought out the red flag, whilst the southern part remained dry.

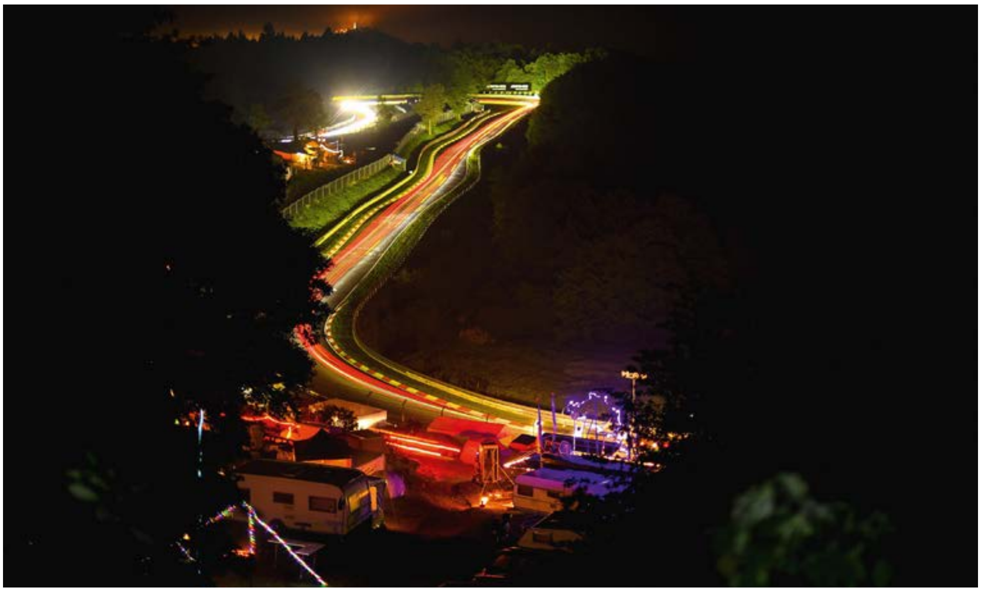
'Although extreme, the Nurburgring is the best place to get such varied real-world conditions all within one lap,' explains Dumbreck. 'There are bumps, surface and camber changes, as well as kerbs and of

The rapid rate of development allows continuous experimentation

Motorsport provides a realistic platform to rigorously test the latest concepts in a wide range of extreme conditions

In endurance racing the durability of the rubber is as important as the lap time it brings, which helps road tyre development

For this year's running of the Nurburgring 24-hours Falken ran a BMW alongside its Porsche (above) to gather new data



With running during the night, and the infamous weather in the Eifel Mountains, the 'Ring 24-hours is a serious test for tyres

course the traffic. It provides a great venue to test tyres to the very limit, and in GT3 terms, against the competition, too.'

Despite the monumental engineering effort to simulate reality using ingenious software packages and machines, there is currently still no substitute for testing in the real-world environment. With even steady state simulations inducing some form of error, using these tools to predict ultimate performance magnifies these uncertainties.

Another advantage of using race tracks as proving grounds is that engineers can analyse how their tyres will tolerate the most brutal of environments, which could never be accurately simulated. Racing demands tyres to cope with high levels of downforce and lateral loads, but also perform at speeds of 372.5km/h (F1), survive stints of 54 long laps (Le Mans), and endure track temperatures ranging from 15degC to 61degC (F1 again).

There is no time for mercy in motorsport. Teams expect to run their tyres to life with no problems, because by constantly pushing the performance envelope of that rubber, stint lengths can be increased and races can be won.

Data collection

In automotive and motorsport, collecting reliable data is another essential tactic to remaining competitive. It allows teams and manufacturers to analyse, understand and react quickly. This is why car giants test vehicles on a dynamometer for months and why Formula 1 teams generate around 140GB of data per race – it's the same for tyre manufacturers.

Every lap a racecar completes provides tyre engineers with detailed information on pressures, bulk and surface temperatures as well as tyre energies and wear rates. It could take months of dyno testing to gather the equivalent amount of tyre data generated from a single race. 'We send sections of used tyres back to Japan for analysis and to determine how the construction and chemical compounds have reacted during the race – our racecars are essentially development labs and this year we will have two with different set-ups; the BMW M6 and the Porsche 991,' Dumbreck says.

This has generated an array of technologies that have descended directly from race to road. 'Our race spec compound found its way into Falken's high performance products and Falken uses the same tyre bead profile on our road car tyres after learning from what worked best on the track for us as drivers,' says Dumbreck.

So, as manufacturers continue to exploit the world's race tracks as their proving grounds, the DNA of your road rubber will forever be related to those motorsport tyres.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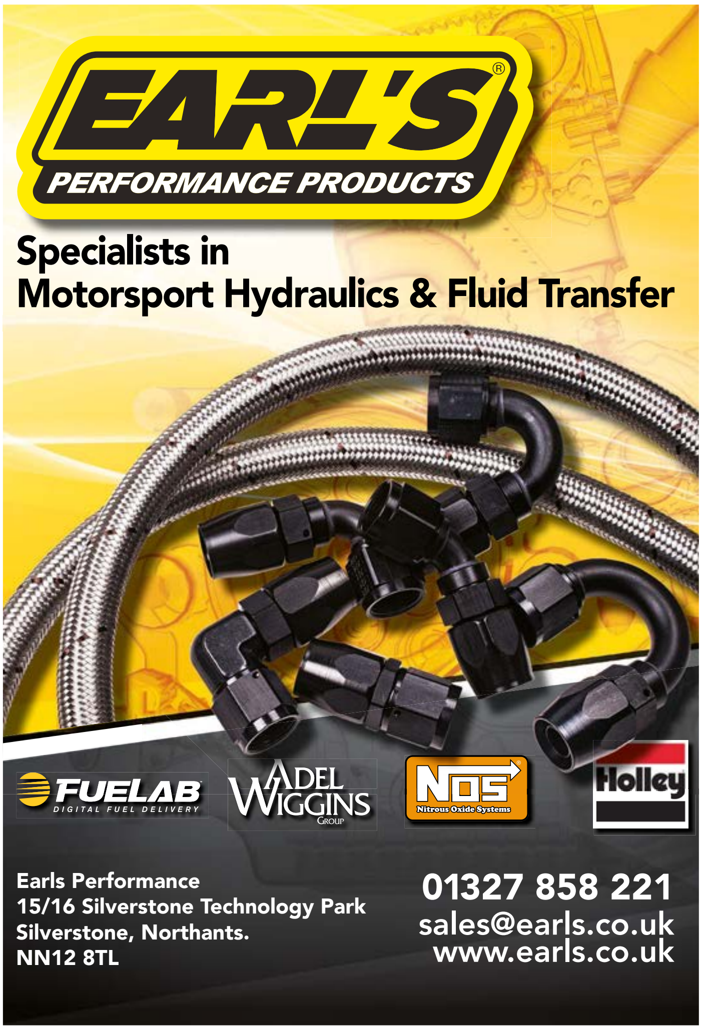
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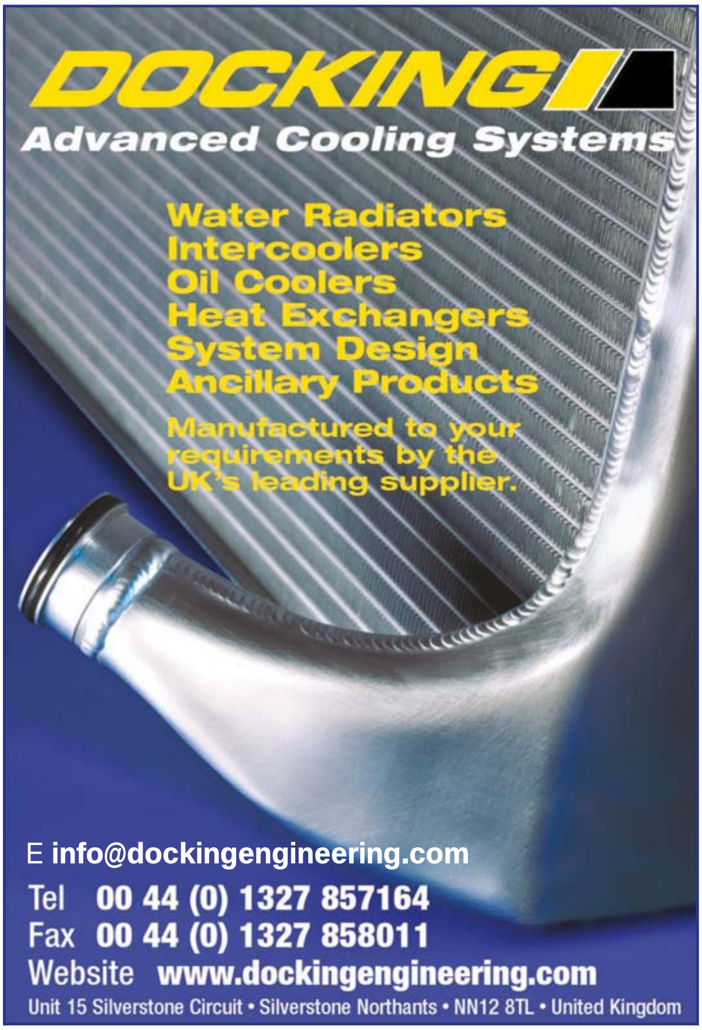
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We can work it out

Our numbers man argues that there's still a place for engineering analysis in modern motorsport – then does the sums to prove it

By DANNY NOWLAN

When it comes to predicting the performance of a car the tyres can be a grey area – which is where traction circle analysis comes into its own

One of the great paradoxes of motorsport is that it's always had a love/hate relationship with technology and engineering analysis. As the principal of a motorsport simulation company I'm in the frontline of this. If there is one thing that I have observed over the years is this is a relationship which is like Jeckyll and Hyde on acid. On the one part we love to proclaim how we as a sport embrace technology, but the millisecond someone develops a winning technology such as active suspension, it doesn't take very long before it is banned.

The other thing that I have observed is that apart from the upper levels of the sport (F1 and NASCAR) there is a burbling fear that borders on hysteria of anything that resembles an analysis that is more complicated than 1 + 1 = 2.

This all raises an important question: is there a place for appropriate engineering analysis in motorsport? I would contend that not only is it necessary, if you are going to be competitive you're insane not to use it. Also, for our long term survival if we don't start embracing this we might be dooming our sport to irrelevancy.

To kick off this discussion it might be instructive to look at what our cousins in the aerospace industry are up to. Recently I was at a technology conference hosted by one of my distributors, Altair Engineering. In a keynote presentation by Airbus it was said that for an aircraft such as an A350 to pass its airworthiness tests, the load cases can be verified by simulation analysis on it's own (FEA in particular). Let me just say I don't agree with that. As a case in point, you only have to look at the complete and utter train wreck that is the F-35 JSF programme to understand the limitations of a purely simulation approach. However, the fact that organisations as conservative as the Federal Aviation Administration are even contemplating this makes us in motorsport look like dinosaurs.

The critical question is: how can we apply this so we can know what our racecars are doing and more importantly we can make them quicker?

It will give you a very good handle on the set-up sensitivity of the car

The first case study I want to present is understanding and quantifying tyres. We all know that when it comes to performance prediction of racecars the two grey areas are tyres and aero. Also, anyone who has been in this business more than 30 minutes knows that most tyre test rig results are very limited in terms of their practical use. Consequently, if you are to stand any hope of actually engineering a car as opposed to guessing, you had better be applying some engineering analysis.

Traction man

In order to classify what the tyres are doing let's review the second order traction circle radius *vs* load methodology to quantify the traction circle. The reason I'm reviewing this is because it's breathtakingly simple and it gives you the mathematical language to describe what your tyres are doing. To summarise, the technique revolves around representing the traction circle radius as a function of peak force *vs* load. This is represented graphically in **Figure 1**.

Mathematically we are representing the above as shown in the equation:

$$TC_{RAD} = k_a(1 - k_b \cdot F_z) \cdot F_z$$

where:

TC_{rad} = traction circle radius (N)
k_a = initial coefficient of friction
k_b = drop off of coefficient with load
F_z = load on the tyre (N)

So the way we apply this is simple. The first thing we do is look at some race data, or use a tool like the ChassisSim track replay feature to get the loads. This is illustrated in **Figure 2**.

Once we have done the above we then use the static force balance to determine the initial co-efficient of friction and this allows us to fill in the blanks of **Figure 1**. I described this in depth in my article on creating tyre models from scratch (*RE* Feb 2016, V26N2) so if you want details look that up, or watch the tutorial on the ChassisSim YouTube channel. But the key question here is why bother with all of this?

Firstly, for a first look it gets you a really good correlation across the speed range. This way you know that you are not in fantasy land. This is illustrated in **Figure 3**. As always simulated is coloured and actual is black here. However, while the artwork is impressive there are two very important takeaways.

The first is you know you have a really good handle on where the load sensitivity is. This can be readily determined by the following equation:

$$L_p = \frac{1}{2 \cdot k_b}$$

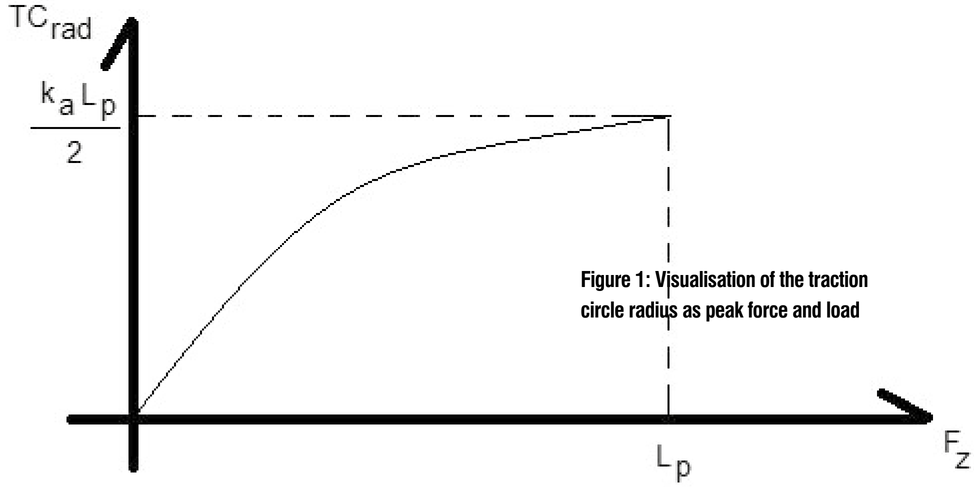

Figure 1: Visualisation of the traction circle radius as peak force and load

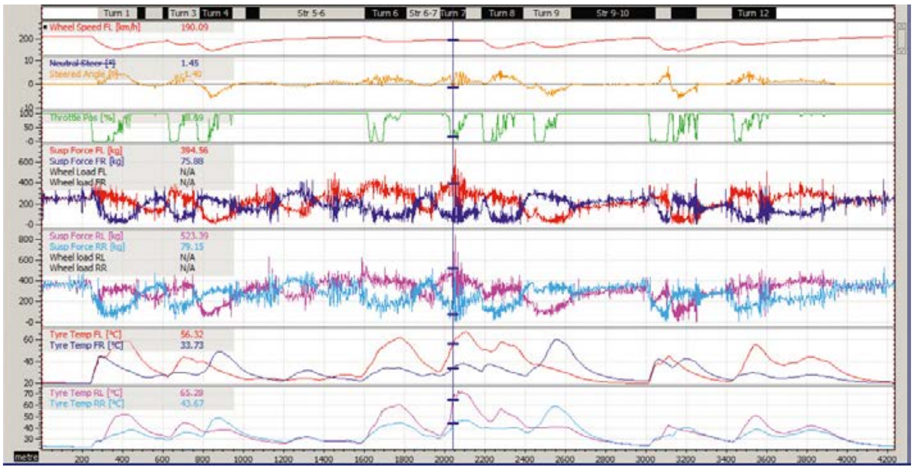

Figure 2: This shows a plot of a Formula 3 car's tyre loads as presented in the ChassisSim track replay feature

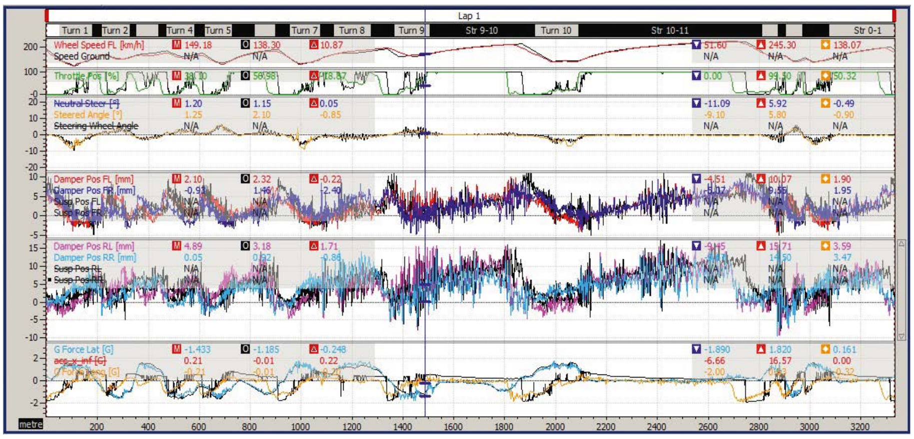

Figure 3: This shows initial correlation achieved using the second order traction circle radius *vs* a tyre load model

This is actually quite significant. In addition to telling you where the tyres start to run out of steam, it will actually also give you a very good handle on the set-up sensitivity of the car. In general the higher the peak load the more insensitive the chassis will be to adjustments. Also, as a rough rule of thumb, the higher the peak load the stiffer you have to run the chassis in both spring rate and bar.

The second important thing to take away is that this forms the critical information that you need to know for the grip balance equation. What I mean by this is that you can plot total racecar grip as a function of lateral load transfer at the front and plot stability index as a function of lateral load transfer at the front. This is illustrated in **Figure 4** and **Figure 5**.

The shape of the curves will also be influenced by the thermal and aero properties of the racecar. However, given what we saw in **Figure 3** this gives you a significant head start in terms of determining what the racecar is up to. Also, this is only possible by using a proper engineering type analysis. So given what this

In some formulas the attitude is if it can't be fixed by a wrench or by fitting a twin turbocharger then it can't be fixed

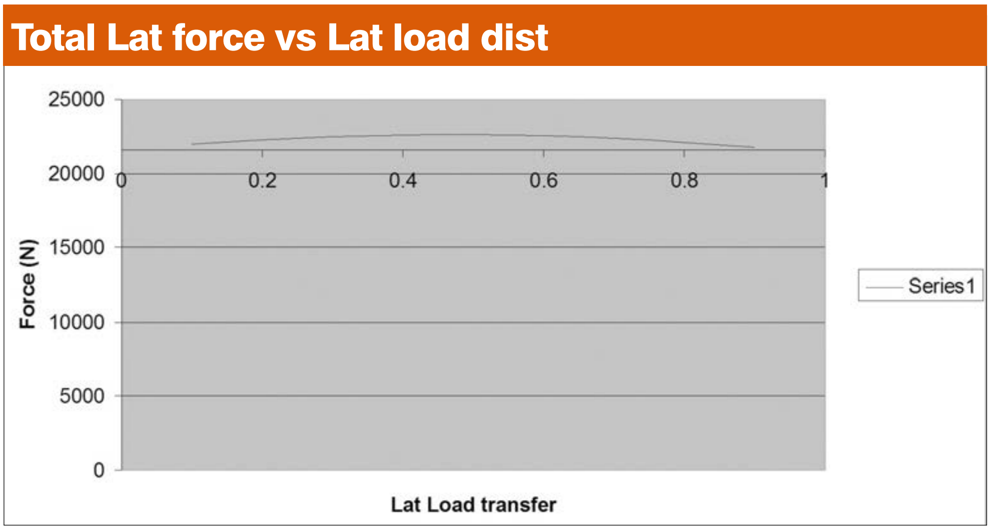

Figure 4: This shows how you can plot the total car grip as a function of lateral load transfer at the front of the racecar

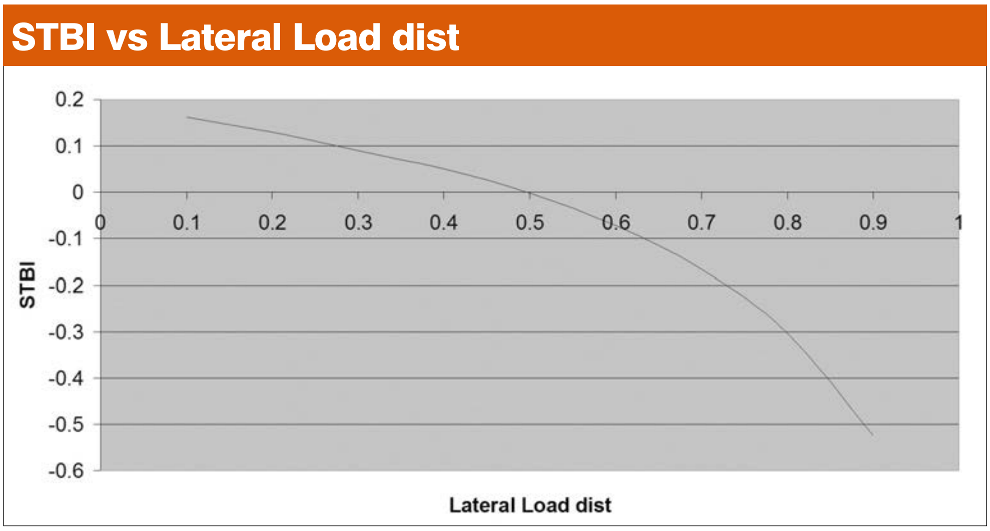

Figure 5: This graph shows how you can plot stability index as a function of the lateral load transfer at the front of the car

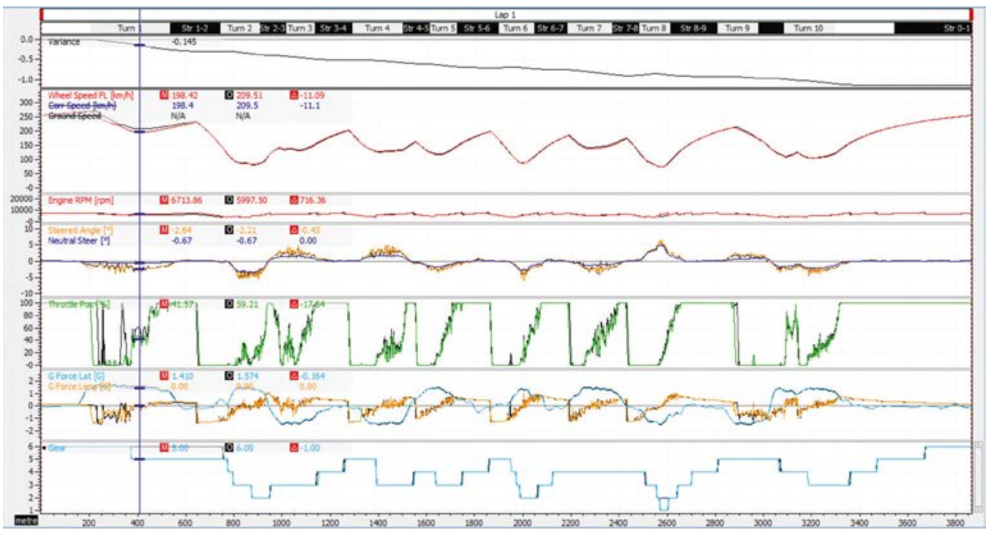

Figure 6: Front dive plane simulation for the NA Autosport Time Attack car helped it go from 17th in 2015 to third in 2016

gives you then why in the world wouldn't you want to make good use of it?

The second example is when ChassisSim was applied to the NA Autosport Evo 6 at World Time Attack Challenge in 2016. This is a most decidedly amateur to semi professional motorsport category. In formulas such as these, the attitude is if it can't be fixed by a wrench or a twin turbo, it can't be fixed. Hats off to the boys at NA Autosport when they knew this wasn't the case and called me in to engineer the car.

Time attack

The year before NA placed 17th, but by using simulation they placed third. The key to it was simulating the effects of the front dive planes, and this is shown in **Figure 6**.

The coloured trace was the standard car and the black trace was with the dive plane change. The difference was two seconds a lap and that is exactly what transpired out on the race circuit. I can tell you right now, had I not done that particular simulation those dive planes would have never gone on to the car and chances are they would have finished in around about eighth to tenth place.

This illustrates the power of having a tool like ChassisSim at your disposal. If you are in an open technical formula, such as the World Time Attack Challenge, then you are crazy if you don't utilise an engineering tool like ChassisSim.

But I say this not just because I have a vested financial interest in this package. I say this because in an open technical formula you need to know where to focus your efforts, and nothing gets this done quite like a battle-proven simulation package like ChassisSim.

Also, given how we are discussing the impact of engineering let's dispel this nonsense that in order to improve the show you need to castrate the engineering content. This is a dangerous myth that motorsport regulators have swallowed hook line and sinker. It's also a cancer that is killing the sport. If you want a case in point look at NA Autosport. In order to leap frog from P17 to P3 they spent $4000 with AMB Aero to get the aero bits and $1100 with ChassisSim for simulation services. If anyone can explain to me how this spoils the show and runs into a spending war then I'm all ears.

Go figure

In conclusion not only does engineering analysis have an important place in motorsport but you ignore it at your peril. As we discussed with the tyre modelling example a proper engineering analysis gives you a key window into what the tyres are doing so you can engineer the car as opposed to guessing the set-up. Also the NA Autosport result at World Time Attack Challenge would have not happened without the backbone of proper engineering tools. So given all this, if you are serious about results, why would you not want to engage in a proper engineering analysis of your racecar?

Interview – Sean Bratches

The third man

Formula 1's commercial operations boss talks about the vision of F1's new owner and tells us why grand prix racing's heritage will never be forgotten

By MIKE BRESLIN

XPB

'What has been a bit overlooked in the last few years is the fan experience'

Gone is the dictatorship in Formula 1. In its place there's a gang of three: CEO Chase Carey, the one with the the background in global media; managing director of motorsports Ross Brawn, the former championship-winning team boss and serial Formula 1 team technical director, who needs no introduction in this particular publication; and the managing director, commercial operations, Sean Bratches.

Bratches is probably the least well-known of the Liberty Media three. Like Carey his background is in global media, particularly at ESPN. He knows his stuff when it comes to media, then. But does he know Formula 1? A fair enough question, when you consider that this year's F1 opener at Melbourne was his first ever grand prix. Of that first race he says: 'I was astonished by how much passion, commitment and enthusiasm was shown by everyone there: fans, drivers, teams, partners. This was a huge boost for me personally. I cannot say it was a surprise, but I was not expecting it at such a high level.'

From there on it only got better from his point of view. 'The welcome has really been fabulous to date. There is increasing confidence from our array of partners at the opportunity we see – partnership and sharing is a big topic for us. We want this to be a partnership between us and all the stakeholders, so as to really work together to make this sport everything it can and should be for its fans. The sport of F1 is for the fans, and we have to make sure we deliver fully on the potential of this sport.'

But does that mean the full potential had not been delivered before Liberty became involved? 'First of all let me say that Bernie Ecclestone has done a tremendous job, he made Formula 1 a great sport product, so hats off to him,' Bratches says. 'What has been a bit overlooked in the last few years is the fan experience and this is why this is our main target. To enable this, we are working on our structure, creating departments within our organisation which were either not fully developed or did not exist before. Marketing and research, for example, as well as communication and digital.'

But it's not just about the fans, there's also a realisation that the revenue and cost structure is far from perfect. 'The sport itself needs to be more viable and healthy, which means, just to be clear, we need collectively to keep the costs under control and increase the revenues, this is an area where there is a lot of work to be done in the next months and years,' Bratches says.

Hosting fees

Another long-held money worry for F1 has been the costs of hosting a race, and it's known that many venues were hoping for a change in the escalating price strategy that had been a hallmark of the Ecclestone reign. They might be disappointed. 'The existing agreements will remain in place and in the meantime we are already talking with the promoters on how the situation can be improved all round for everyone,' Bratches says. 'A successful event means more fans and therefore more income for the promoter: this is why we want to support the promoter in their efforts to enhance the fans experience. When we talk about a more sustainable and viable sport, we also refer to the promoters, who are a very important part of our family.'

But for F1 to continue to be a viable sport it needs to be entertaining. For someone from outside of Formula 1 the delicate balance between technology and the show must be a difficult facet to understand, yet Bratches seems to have grasped it. 'I think they're both part of what makes the sport special. It's a competition on one hand, but the technology and engineering are obviously part of what creates the mystique and interest in the sport … But of course the pure sporting aspect must also be considered. Our drivers are our biggest stars: we want to put on events that are great, shared with our fans, exciting action with great stars. We want the drivers to ultimately be the shining lights, not to be a sport driven by engineers, but a sport where the engineers are adding value.

'To achieve that target, we're putting together a group of technical experts led by Ross Brawn,' Bratches adds. 'They will work closely with the FIA and the teams to define a set of technical and sporting regulations which will help Formula 1 grow healthier and more viable.'

Heritage races

It's clear that things are changing in F1, then. But not everyone likes change. Because change in F1 has often meant losing something good. But Bratches says he's aware of the sport's legacy, and Liberty are actively doing something to nurture

Liberty is keen to add to the single US grand prix at Austin (pictured) and is looking at holding a race in a 'destination city' such as Miami, New York or Las Vegas

XPB

it. 'The history of F1 is heroic, full of drama and colour. It is a key asset of the sport and one that we will do our utmost to preserve and revere,' he says. 'This is why, for instance, we pushed hard to reinstate in the calendar historical races such as the French and German Grands Prix [questions over Silverstone's future in F1 arose after this interview]. There are traditions that are integral to the sport and we want to build on them. We know that we have a lot of fans who grew up following F1, as did their fathers. This is the core of our audience, we will not let them down. Our target is to enlarge the fan base, engaging new fans across all cultures and ages.'

That last line is important, it's about the old and the new. And the new means new media – a space in which F1 has been woefully absent for years. Bratches says this is now right at the top of his to do list. '[We need to] increase the satisfaction of the fans who experience Formula 1 at the races and across their screens, be it a smartphone, a TV set, a computer or whatever device they can use to engage with us.'

So far this appears to be bearing fruit, too. 'For the time being I can only mention the first figures we had from the social media channels which are up significantly across the board and we continue to see that growth,' Bratches says. 'Digital is an incredibly important aspect of how we are going to engage the next generation of fans.'

US expansion

Part of Liberty's new philosophy is also to expand Formula 1 around the world, and particularly in its US home. But could F1 really capture the hearts and minds of a US audience weaned on NASCAR? 'It's important that Formula 1 will become more popular in the United States,' Bratchces says. 'This is why one of our targets is to increase the number of races there, adding to the current venue, Austin, in a destination city such as New York, Miami, or Las Vegas. We continue to evaluate those things, but our main priority is making the existing events – this year we have 20, the next 21 – great. It is quality over quantity for us. With regard to NASCAR, it's not really a matter of rivalry; this is not our target.'

So, what of the future for Formula 1? Where will it be five years' down the line? 'Stronger, more sustainable, more attractive, these are our targets and we're fully committed to reach them,' Bratches insists.

RACE MOVES

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Mike Gascoyne, the former Caterham, Toyota and Renault technical chief, is to return to Formula 1 to redesign the two-seater F1 Experience car. Gascoyne, who has recently focused on his consultancy business, has been signed up as the two-seater's technical director before the programme is expanded to run at every Formula 1 grand prix next year.

Formula 1 has appointed **Ellie Norman** as its head of marketing. Norman joins F1 after spending five years at Virgin Media as head of advertising. Prior to this she held the position of communications manager at Honda Motor Europe.

The Sauber F1 team has recruited former Mercedes engineer **Ian Wright** as its new head of vehicle performance. Wright, who has already started work at the Swiss outfit, started his F1 career as senior engineer at BAR and stayed on when it became Honda, then Brawn GP and then Mercedes. He left Mercedes in 2014 to take up a role outside of F1.

Cranfield University has awarded an honorary doctorate to **Adrian Reynard**, a former student at the establishment – before he left to take up a chief designer post at an F1 team in 1975. Reynard designed his early racecars using the Cranfield wind tunnel and also assisted the university in the design, development and delivery of its hugely successful Motorsport MSc course.

Motec Holdings, the parent company of engine management and data acquisition company MoTec, has undergone a change of ownership with **Richard Bendell** selling all his interests to **Philip Morriss**. The latter now owns 100 per cent of Motec Holdings.

After six years as team principal at the British Army Sports Car Racing Team (BARCT), **Captain Mark Saunders** (Royal Electrical and Mechanical Engineers) has been promoted and will now head up all four-wheeled activity in Army Motorsport. **Major Farard Darver** (Royal Logistic Corps), steps up from team manager to become team principal, with **Captain Rikki Abel** (also RLC) assuming the team manager role.

Colin Smith, the former NASCAR Digital Media vice president, is to join the Miami-based Motorsport Network media organisation as its new chief executive officer. Prior to joining NASCAR Digital Media, where he worked for five years, Smith spent 15 years with Raycom Media/Raycom Sports.

Forrest Lucas, the founder of Lucas Oil Products, has been presented with the Bob Russo Heritage Award by the Motorsports Hall of Fame of America (MSHFA). The company was founded in 1989 and Lucas has been recognised for his support of a wide range of motorsport disciplines. 'Few people have done more to promote motorsports at all levels in the United States over the past 25 years than Forrest Lucas,' said MSHFA president **Ron Watson**.

Stuart Cosgrave, one of the men behind Ireland's first permanent race circuit, Mondello Park, has died after a short illness. After his time at the circuit Cosgrave ran a chain of indoor karting venues in the Irish Republic.

Vic Edelbrock Jr, known for the US-based aftermarket automotive parts business that bears his name, has died at the age of 80. Edelbrock Jr took control of the business after the death of his father in 1962. **Vic Edelbrock Sr** originally founded the business as an auto repair shop in Los Angeles in the early 1930s and it is now well-known on the US drag race and short track scenes.

The prize for the Infiniti Engineering Academy, which includes paid work placement at the Renault F1 team, has been expanded, with two roles in the Renault UK Clio Cup paddock now a part of the prize package. One of these is to be a part of the championship's behind-the-scenes data-logging engineering team, while the other is to join its scrutineering operation.

Vasseur takes Kaltenborn's place as Sauber team boss

Former Renault F1 boss Frederic Vasseur is now the team principal at Sauber, taking on the role vacated by Monisha Kaltenborn, who departed the team after a difference of opinion with its owners in late June.

Vasseur emerged as favourite to take over the role shortly after Kaltenborn left, but Sauber operated without a team principal both in Azerbaijan and then the next two races in Austria and the UK. He started work at the Swiss operation the day after the British Grand Prix.

Frederic Vasseur is now in charge at Sauber F1 team

As well as having been appointed team principal of Sauber F1, Vasseur has also been named as managing director and CEO of Sauber Motorsport AG.

Vasseur had been hired by Renault as racing director for its works team return to F1 in 2016 and was promoted to team principal later that year. He split with Renault in the off-season by mutual consent.

A trained engineer, Vasseur came to prominence in international racing due to his success with his ART junior formula squad, particularly in GP2.

Sauber chairman Pascal Picci said of Vasseur's hiring: 'Frederic Vasseur's long and successful career in top level international motorsport speaks for itself, and we are thrilled to welcome him.'

Vasseur said: 'I'm very proud to be joining Sauber Motorsport AG, and wish to thank the company's shareholders for their trust in me. I've been impressed by the facilities in Hinwil [the team's base] and by the talent and ambition of the workforce, and I very much look forward to complementing the team with my experience and determination.

'I am convinced that we will achieve ambitious targets,' Vasseur added. 'I cannot wait to start working with our drivers, engineers and staff. I look forward to contributing to the next important phase in the development of the team.'

OBITUARY – Barry Bland

The man who was largely responsible for making the Macau Grand Prix for F3 cars the hugely prestigious event it is today has died at the age of 71.

Barry Bland started his motorsport career at the British Automobile Racing Club as competitions secretary and a race-meeting organiser, after a brief spell as a driver. In 1971 he joined Motor Race Consultants, where he worked for the rest of his life, organising race entries, logistics and insurance for events around the globe. But his claim to fame must be the Macau race, which came about after plans to replace a struggling Formula Atlantic counter in the Far East city with a Formula 2 race fell short due to the narrowness of the track at one point on the circuit. F3 was a viable alternative, however, and since that first event in 1983 the Macau Formula 3 Grand Prix has never looked back.

Through the years Bland worked hard to make sure the grid for the event was the very best possible, often fixing deals between drivers, teams and local Macau-based sponsors. It was only last year that his involvement with the Macau GP came to an end, after a disagreement with its new organiser.

Bland was also behind the Masters of F3 race at Zandvoort, originally known as the Marlboro Masters, and he was the original president of the FIA Single Seater Commission, before being succeeded by Gerhard Berger in 2012.

Barry Bland 1946-2017

XPB

Unmistakably Macau: Barry Bland, who has died at the age of 71, was the man behind the well-known Formula 3 event

RACE MOVES – continued

XPB

The Motor Sport Industry Association (MIA) has recognised the career of **Pat Symonds** with the presentation of its award for Outstanding Contribution to the Motorsport Industry. Symonds began his career in motorsport by designing championship-winning Formula Ford cars for Hawke and Royale, before moving into F1. Most recently chief technical officer at Williams, he is now a pundit with Sky TV.

Dave Rogers, the former crew chief on the No.19 Joe Gibbs Racing Toyota in the NASCAR Cup series, has now taken up the position of technical director for the organisation's Xfinity Series programme, overseeing the No.18, No.19 and No.20 cars in the second-tier series. Rogers had been a Cup series crew chief with JGR since 2010

US motorsports PR firm Sunday Group Management has hired motor racing media veteran **JJ O'Malley**. O'Malley has had a long career in the sport, having served as news editor at National Speed Sport News and spent 33 years with ISC/NASCAR, including 14 years as director of communications at Watkins Glen, as well as working at Homestead-Miami Speedway, ISC Publications, Grand-Am and IMSA.

Barry Rogers, the team principal at Australian Supercars team GRM, has been voted on to the championship's rule-making commission, taking the place of former Walkinshaw Racing HSV team principal **Adrian Burgess**.

Jim Derhaag is to leave the Trans Am Race Company's (TARC) ownership group in order to focus on his Derhaag Motorsports business. The three remaining primary partners within TARC, **David Jans, Mike Miller** and **Tony Parella**, have entered into an agreement with Derhaag to equally acquire his interest within the company, all three now each owning an equal share. **John Clagett** and **Simon Gregg** will retain their minority shareholdings in TARC.

Brent Dewar has been elevated to the position of president of NASCAR. Dewar joined the organisation as chief operating officer in 2014. He will now continue to serve on the NASCAR board of directors and will work closely with chairman and chief executive officer **Brian France**. Prior to joining NASCAR Dewar enjoyed a three-decade career as a global automotive executive.

Ferrari boss **Sergio Marchionne** has confirmed that Lorenzo Sassi has left the company's Formula 1 team. Marchionne told Italian publication *La Gazzetta dello Sport* that the F1 team's former engine chief has now moved on to work at parent company Fiat Chrysler.

Norie Baird, an employee of Charlotte Motor Speedway for 30 years – who was also responsible for many safety procedures now in place in NASCAR – has died at the age of 72. In 2010 Baird was honoured by NASCAR with the Excellence in Track Services Award. He retired from the speedway in 2012.

GMS Racing has named veteran crew chief **Mike Ford** as competition director for its NASCAR Xfinity Series team. Tom Ackerman continues to serve as competition director for its NASCAR Truck Series programme.

◆ 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 email with your information to **Mike Breslin** at **mike@bresmedia.co.uk**

AUTOSPORT INTERNATIONAL
THE RACING CAR SHOW

Planning ahead

There may be half the season still to complete, but it's not too early to prepare for the Autosport International Show

Tickets have gone on sale for both the trade and the public areas for the Autosport International Show, held on January 11 to 14, 2018, at the Birmingham NEC in the UK.

Ferrari has already been announced as the main feature for the show, with an exciting centrepiece to be created showcasing the lineage from its sportscars through to F1, courtesy of Clienti Corse, Ferrari's exclusive client racing programme.

Since 2003 the F1 Clienti department has put up for sale Formula 1 cars that are at least two years old and allowed buyers to use them to the full. The company also caters for the privateer classes that race the latest Ferrari 488 GT in endurance competition on both sides of the Atlantic, and so the centrepiece event, in Ferrari's 71st year, is sure to be epic.

This year, once again, *Racecar Engineering* will team up with the Motorsport Network's UK title, *Autosport*, to promote the engineering section of the show, held on Thursday, January 11 and Friday, January 12.

With all the talk of Brexit and how that will affect the UK motor racing industry, this will be the ideal time to speak with other companies in the industry, or sell your skills.

Autosport International continues to be the premier show for exhibitors from across Europe, Asia and North America – attracting the industry's largest companies since its debut in 1991. This pre-season event provides a platform for industry professionals to meet in a business-to-business environment, generating an estimated £1bn of global motorsport business.

The UK remains the home of the global motorsport industry, driving £9bn to the UK economy, and it is responsible for more motorsport related innovations than any other country. Autosport International and Autosport Engineering plays an integral part in this growth and development, providing a stand-alone two-day networking opportunity to keep up-to-date with the industry's latest technological advancements and leading companies. You need to be there.

Products at ASI

AP Racing, the leading manufacturer of performance brake and clutch systems for road and racecars is soon to launch World Radi-CAL 2 – a new forged 4- and 6-piston caliper range. Available to order in the final quarter of 2017, the latest brake is said to offer less mass, improved rigidity and better cooling characteristics.

A major innovation in braking technology, the calipers incorporate all of the features demanded by the road market, including dirt seals, an attractive painted finish and noise abatement solutions.

The Radi-CAL 2 incorporates patented technology allowing road users to experience superior performance, from the race track to the street.

The core product range from AP Racing includes clutches, calipers, discs, pads, master cylinders, pedal boxes and air jacks, as well as road and competition brake systems for motorcycles.
AP Racing, stand E380.

LifeLine's new Zero 3620 Fire Marshal is said to provide exceptional performance and offers a significant cost reduction when compared with the current generation of FIA 8865 approved systems.

Meeting the FIA's demanding 8865 standard it has been tested and developed for use with most fuels, including unleaded petrol, diesel and E85.

Housed within a single fabricated aluminium cylinder, the latest spec Fire Marshal is unique within the industry, discharging into both the engine bay and cockpit, using environmentally friendly 3M Novec 1230 suppressant.
Lifeline, stand E185.

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NEW FOR 2018, child ticket prices for those under 16 have been reduced. Full ticket price information is as follows:

Standard: Adult £35pp, Child (6-15yrs) £17

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show (children under five years of age go for free). Ticket price includes the £2 booking fee per ticket.

Paddock Pass: Adult £46pp, Child (6-15yrs) £27.50pp

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show (children under five years of age go for free). Access to backstage Paddock area in the Live Action Arena, Paddock Guide and access to driver autograph sessions.

Family Pass: £87 (2x Adult and 2x Child of 6-15yrs).

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show. Valid for standard tickets only. The price includes booking fee charges.

VIP Club: £127 (no VIP Child ticket available).

Ticket includes entry into Autosport International, the Live Action Arena and Performance Car Show. In addition VIP Club includes free parking, seat at VIP enclosure in the Live Action Arena, complimentary drinks and canapes, VIP gift bag and much more.

For more, visit www.autosportinternational.com

ASI is the start of the motorsport year for many in the industry and anyone who's anyone will attend the NEC in January

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History repeating

The news that Joest Racing will take over the Mazda Prototype programme in the IMSA United Sportscar series is big. It signals a return of one of the great endurance racing teams, it signals intent from Mazda in the US, and it signals that the competition in the IMSA series is about to take a big step up.

It also signals a change in focus for endurance racing, from Europe to the US, and we have been here before. Back in 1998, the FIA GT Championship was the place to be with Mercedes, Porsche and Dodge involved. The cars were spectacular, the drivers high calibre, but even then there were warning signs. BMW had left at the end of the 1997 season citing an escalation in costs, and at the wrong end of a 10-0 drubbing, Porsche left at the end of the 1998 season. Then Mercedes left.

Focus for the manufacturers turned to Le Mans, and the 1999 race was well subscribed: Mercedes, Toyota, BMW, Cadillac, Nissan and Panoz were all represented in the top class. But there was little else supporting Le Mans, other than a race series in North America, that had started with the 1998 Petit Le Mans at Road Atlanta.

By 2000, the American Le Mans Series was the place to be, with factory teams from Audi, BMW, Cadillac and of course Panoz. Dodge, Corvette, BMW and Porsche were vibrant in the GT classes, and for several years this was the Holy Grail. The circuits were not really up to standard for these European cars, but accidents were mercifully few. The racing, the support and the package for the teams was valuable, and there was a lot of fun to be had off-track too.

Yet the Europeans weren't done yet. John Mangoletsi and Stephane Ratel, with backing from David Kennedy and Martin Birrane, were busy trying to rejuvenate sports prototype racing in Europe. With Patrick Peter, the ACO started the Le Mans Endurance Series, which became the European Le Mans Series, and eventually the International Le Mans Cup (ILMC) that, with the manufacturer backing, morphed into the FIA World Championship.

Audi, Toyota and Peugeot were due to race in the series, but Peugeot ran into its own financial difficulties before the World Championship even began and killed its programme at the 11th hour. Audi supported it staunchly, Toyota pushed the button to bring cars earlier than planned to help it grow, and then in 2014, Porsche arrived. Few remember that Nissan, too, had a full WEC programme, but that was quickly cancelled.

Audi followed it out of the door in 2016, Porsche will (likely at time of writing) leave at the end of 2017, and Toyota has the option of continuing alone, but with no manufacturer even looking at the series now that the new plug-in hybrid plans have been announced (Peugeot said it would just wait for the series to collapse before it stepped in, probably with a mild hybrid system), what is it waiting for? With no one new on the horizon, it could continue to 2019 with the current car, but it is now up to the organisers to make a decision on how to get manufacturers to even consider the FIA World Championship.

In the US, with Penske with Acura, Joest with Mazda, Taylor with Cadillac, ESM with Nissan and others looking at it carefully, it's clear that teams and manufacturers are looking Stateside for maximum bang for their buck. That's not to say that the World Championship will cease to exist (the GT World Championship was introduced this year and is critical to the success of the class) but there needs to be clear, strong direction, and the teams and manufacturers have given a clear indication as to their preference. We can point to 'Dieselgate' as one reason why Audi and Porsche, both VAG partners, withdrew. We can point to government targets for emissions as reasons, too, and the need for zero emission cars, which explains Formula E.

In all areas Joest's involvement is something of a game changer

In January, Joest Racing's Ralf Juttner was prowling the paddock at Daytona looking for new opportunities for his operation and the organisers spoke of a need for a team such as Joest to come in and take on Wayne Taylor Racing. The balance of performance was made all the more difficult by the disparity of teams in the paddock. There is no doubt that Cadillac brought a gun to a knife fight, but the job of balancing will be easier if teams with experience of tuning electronic systems, for example, were to compete in the US.

In June, Multimatic's Larry Holt said that he would be taking over the development of the Riley chassis, as he was not happy with the way that it was going. We thought that, through Multimatic's link with Ford, it was for that reason that he decided to step in. Joest's involvement in its project puts those comments into a slightly different light. Ford may still come, but the programme needed a change anyway.

So, in all areas Joest's involvement is something of a game changer. But change is only temporary. The World Championship that the manufacturers fought for was delivered, and now the manufacturers are in the process of leaving prototype racing in the WEC. The FIA has dug itself into a hole as it killed off Stephane Ratel's GT1 World Championship in favour of the FIA WEC, and this year there is a GT World Championship for GTE cars, too. History does have a habit of repeating itself, doesn't it?

ANDREW COTTON Editor


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