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Will Power won the 2022 IndyCar series at Laguna Seca but as IndyCar prepares for its next generation of engines in 2024 it has still to reveal the details

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Honda's hard history

From blown bottom ends to 10 time Manufacturers' Champion in IndyCar

Earlier this year, Honda tested its all new, E85 biofuelled, 2.4-litre, twin-turbo V6 internal combustion engine that will power its IndyCars from 2024 onwards. The new motor has been built to similar specifications as the company's 2.2-litre, twin-turbo V6 engines IndyCar currently runs. However, unlike the existing cars, the new PUs will form part of a hybrid system with a total output around 700bhp.

Honda's development programme for the 2024 engine seems to be running smoothly but, despite the manufacturer's recent successes in IndyCar, it struggled initially with the series.

The company's investigations into IndyCar began in Japan in 1989. At that point, Honda was confident it could tackle the challenge using its wealth of experience with high performance race engines in Formula 1. At the time, Honda R&D in Japan could not do both Formula 1 and IndyCar engines, so partnered with Mugen for the engine work.

Racing division

The first engine for the series was completed in 1992. At the same time, the company decided it needed a racing division in the United States to manage relationships with teams, maintain the engines and provide trackside support in the series, so launched Honda Performance Development (HPD) in Santa Clarita, California. The facility officially opened on 1 April 1993, as a subsidiary of American Honda.

Within weeks of launching HPD, Honda took its first ever IndyCar V8 to test in a Lola chassis at its proving grounds in the Mojave Desert. The 1993 Honda-Mugen engine had been well developed and performed well on the dyno before it arrived in the United States, and there was little work to be done to have it running in the car for the test.

The Honda-Mugen engine was a mule designed for learning about V8s and the combustion characteristics of methanol and, although the car did not compete in any races that year, HPD did run tests at the Indianapolis Motor Speedway in June to see how the engine would perform in an Indy race scenario.

Parallel lines

In parallel to this testing, Honda R&D in Tochigi, Japan was developing an all new engine for the 1994 IndyCar season. For the most part, the '94 engine was designed by Honda engineers, without the help of Mugen. Unfortunately, the engine proved to be a disaster.

The issue was Honda R&D's experience had been foremost in Formula 1, which had gone from a turbo V6 to a V10 to a V12, skipping V8s entirely. Consequently, the engineers lacked experience with high-speed V8s and the particular phenomena of their firing harmonics.

The company's inexperience led the IndyCar programme down entirely the wrong road and on to many failures.

Six-time IndyCar series champion, Scott Dixon, drives a Honda test chassis with the company's new internal combustion engine on a modified version of the 13-turn, 2.6-mile Indianapolis Motor Speedway road course

The problems with the engine were related to its core architecture, with the majority of failures occurring in the bottom end, the crankshaft failing first and then the block, which had an effect all the way up to the valvetrain. This fundamental weakness in design severely limited the engine's development potential. After the engine failed several times under racing conditions, it was clear to the competition that not only did Honda not have the speed, it had a severe reliability issue.

Immediately after failing to qualify for the 1994 Indy 500, Honda R&D started from scratch once again, this time with a new engineering team and a completely new engine design, which it introduced at the 1995 Indy 500.

The story from there could not have been more dissimilar. A Honda-powered Reynard qualified on the front row for the race and was highly competitive until its driver passed a safety car and was black-flagged.

Feel the burn

The new engine was an amalgamation of everything Honda's engineers had learnt from the previous season about the burn characteristics of methanol, using turbochargers on a methanol engine, valvetrain design, combustion chamber and port design, and how to design a bottom end to handle the power and stresses of IndyCar racing.

That season brought the manufacturer several good finishes and established a winning relationship between Honda and IndyCar.

From 1995 onwards, Honda began signing deals with top teams such as Chip Ganassi Racing, Team Green and Penske, and went on to see massive success in the IndyCar racing programme.

Twenty five years after winning its first IndyCar Manufacturers' Championship, Honda clinched its 10th overall and fourth consecutive IndyCar series Manufacturers' Championship in 2021. Honda power also triumphed at the 2022 Indianapolis 500 for Chip Ganassi driver, Marcus Ericsson, who won the 106th running of the world famous race in May.

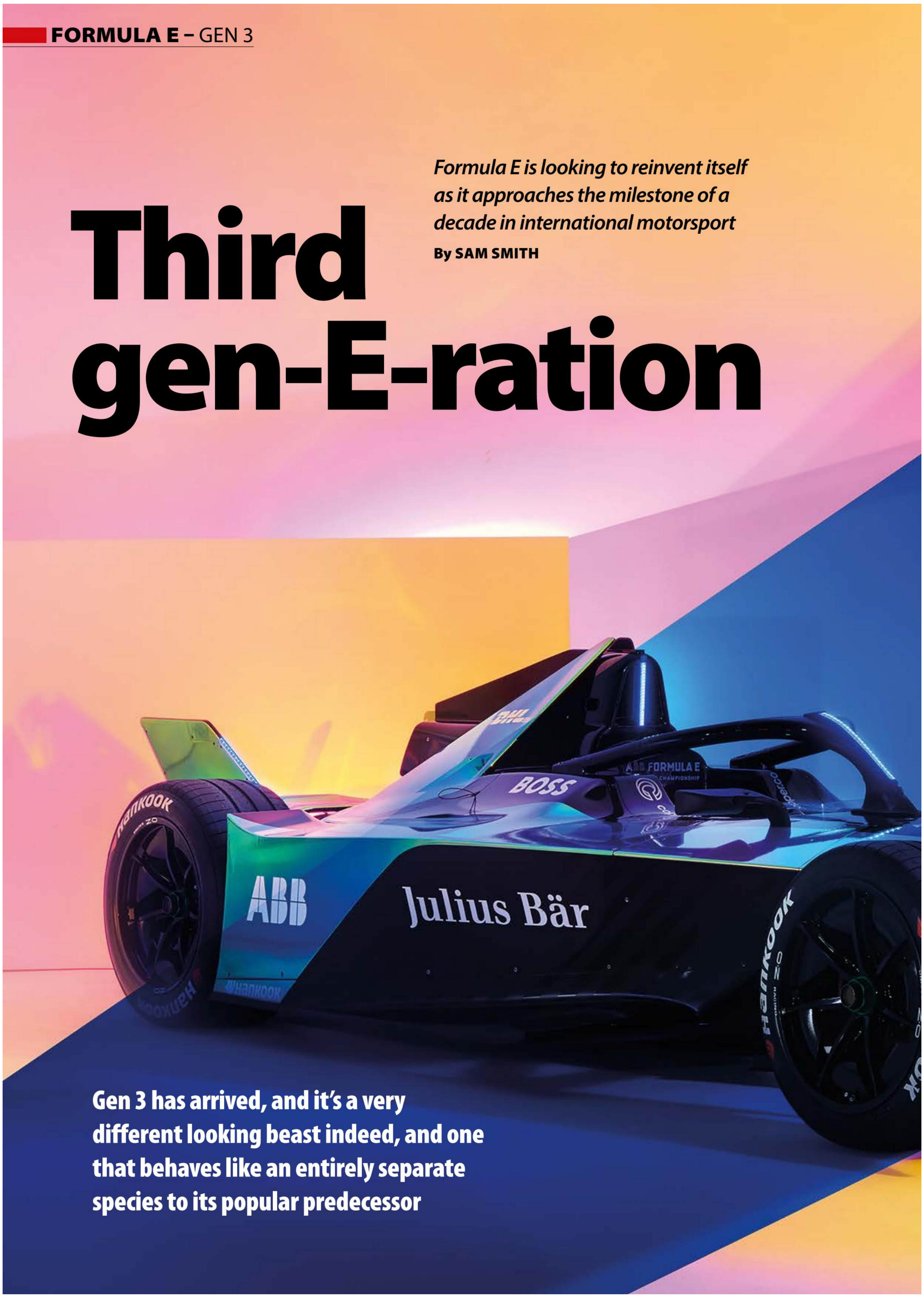
The moral of the story? If at first you don't succeed, try try again.

The engineers lacked experience with high-speed V8s and the particular phenomena of their firing harmonics

Third gen-E-ration

Formula E is looking to reinvent itself as it approaches the milestone of a decade in international motorsport

By SAM SMITH



Gen 3 has arrived, and it's a very different looking beast indeed, and one that behaves like an entirely separate species to its popular predecessor

Initially given little chance to survive when first mooted in 2012, the all-electric series has blossomed into a fully-fledged world championship with multiple prestige OEMs and a roster of driving and engineering talent that makes it both one of the strongest and most lucrative forms of motorsport outside of F1.

Technically, its road map has been adaptable, and its sporting structure flexible enough to contend with some serious slings and arrows that have ranged from the widespread ridicule of changing cars between 2014-'18 and the debacle that saw cars running out of useable energy at Valencia in April 2021's infamous 'zombie race'.

The Gen 2 car, a distinctive mix of single seater and Prototype was widely lauded for its striking looks and its propensity to create close (sometimes too close) racing. Now, Gen 3 has arrived, and it's a very different looking beast indeed, and one that behaves like an entirely separate species to its popular predecessor.

Tender process

The new car was born in much the same way as its predecessor, via official FIA tenders that were sent out in 2019. By early the following year, Williams Advanced Engineering had regained the battery deal it lost to McLaren Applied for Gen 2 and Spark had retained the chassis and other central components, such as the front MGU, which was allocated to Atieva (Lucid Motors' tech' arm). But by far the biggest shock was that Michelin was not kept on for a third term as tyre supplier. Instead, Hankook came on board.

And while the technical parameters around the hike in power from 250kW to 350kW and an impressive maximum 600kW regen' capability stole the early headlines, the new rubber is a popular topic of conversation as the opening round, ambitiously slated for mid-January at the Circuit Hermanos Rodriguez in Mexico City, looms on the horizon.

The Gen 3 car is lighter, shorter, narrower and quicker than its predecessor. By how much is still open to debate but it's a faster car, with initial expectations of a top speed just under 200mph. Add in around 95 per cent power efficiency from an electric motor delivering up to 350kW of power (equivalent to 470bhp), and things are looking exciting.

These significant changes inevitably alter things from a design point of view, as Jaguar's technical manager, Phil Charles, notes. 'It's a very different game now in Gen 3,' he says. 'There's some really ambitious targets in there.

'The Gen 3 [car] is about 50kg lighter than the Gen 2 and, at the same time, you've added a front powertrain to the car. There is this extra really cool bit of tech' yet the car has been put on a massive diet.

'These are ambitious targets, a big step for the car, and a big step for the drivers to have to deal with all that extra stuff.'

The new front powertrain, which is said to be a simple enough spec MGU, ensures the regen' on the front axle adds what Charles describes as 'a big extra dimension.'

'It's pushed all the parameters in the car, including the battery target, as we have a really lightweight battery [285kg compared to Gen 2's 385kg] and it's got fast charging, too,' he adds.

But what does that mean from a design standpoint for the manufacturers, of which there are six – DS, Mahindra, Nissan, Jaguar, Porsche and NIO 333?

Power increase

'Just that power increase on its own is big, but also the car is 100mm narrower and 140mm shorter, so it's a much nimbler car,' continues Charles.

'That means the frontal area that's cutting through the air is also smaller, so that changes the aero parameters on the car a bit, too.

'The front tyre is now an open wheel again. There's normally a fairly significant change in the way a car behaves when you cover a wheel, so when you uncover it there's a lot of eddies that flow off the wheel and that affects cooling into the radiators.

'We're excited because the car is a big integration task. Now there's a brake-by-wire system and front power chain kit that we have to communicate with, so we've got to get all of that working together. In terms of bringing all those bits together, it's a big job.'

The manufacturers went through a major simulation process when the initial spec of the Gen 3 cars became known in 2019 but, with a new tyre manufacturer coming in, they were a little hamstrung on the vehicle dynamic elements needed for preparation purposes.

The regen' capabilty of the new car is so impressive (up from 250kW to 600kW) that it has no hydraulic rear axle braking, which adds to the learning curve for drivers, too

Before they could start making decisions on what rear MGU they designed, and what overall powertrain cluster was drawn up, manufacturers needed to work out some of the basic parameters.

'We need to know the tyre, we need to know a bit of aero, and we need to start to do some simulation and work out, first of all, what top speed we're going to do,' confirms Charles.

'Then you need to look at what maximum torque we're going to get from the tyre. That then unfolds and dictates the MGU design because once we've got a peak torque and a top speed, we can decide lots of parameters in the MGU.'

Packaging job

Only after all that was achieved could the packaging strategies begin. The Gen 3 car has some very different constraints with the suspension, especially given the new front powertrain.

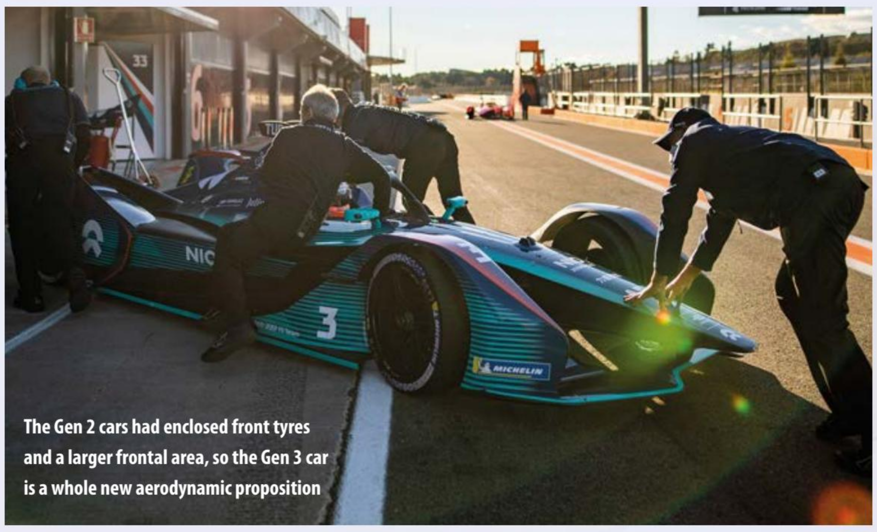
Putting a motor in a relatively small cross section of a monocoque is always tricky but, according to Charles, the work that's been done by Spark and Atieva is 'actually pretty good' because 'they've basically made it in a sympathetic way so that the front powertrain kit can be extracted in one very compact, integrated lump.'

That 'lump' includes the front differential, inverter and motor, but there is still complexity in bleeding and disconnecting the cooling system, which means there will definitely be more to do for mechanics working in the series.

In collaboration with the front and rear powertrains, the new Hankook tyres will be crucial in the overall process of understanding how to get the best out of the Gen 3 car.

'Over the last few years, it's been really good to have the same tyre manufacturer. Now, just changing the tyre is a big change – it's always a tricky thing for a new tyre manufacturer to come into – but given the step change of power, while maintaining basically the same concept, which is a relatively narrow wheel for a racecar and a single compound that can do all conditions, that's really quite tricky.

'We had to get our heads around the fact that both the tyre manufacturer and philosophy was changing.'


The Gen 2 cars had enclosed front tyres and a larger frontal area, so the Gen 3 car is a whole new aerodynamic proposition

Testing has been made more difficult by the fact the new tyre is an unknown quantity, with no track data to work with

Educated guesses

Essentially, the manufacturers have had to make educated guesses at what cycle they expect the new car will go through. Will it be braking harder? Or from a higher speed? Is it likely to be coasting for longer?

'Then you start to say, right, what characteristics on the suspension do I want the car to have to complement the tyre and all those extra packaging bits,' says Charles. 'Things like not having hydraulic brakes on the rear means the forces go into the car in a different way.

'Now you're pinching the axle in the middle of the car. That puts different forces

Comparison of Gen 2 and Gen 3 car specs

	Gen 2	Gen 3
Overall length	5200mm	5016.2mm
Overall height	1063.5mm	1023.4mm
Overall width	1800mm	1700mm
Wheelbase	3100mm	2970.5mm
Minimum weight (including driver)	900kg	840kg
Max power	250kW (335bhp)	350kW (470bhp)
Max regen'	250kW	600kW
Energy recovery	25%	40%
Top speed	280kmh / 174mph	320kph / 200mph
Powertrain configuration	Rear only	Front (spec) and rear (manufacturer)

'We had to get our heads around the fact that both the tyre manufacturer and philosophy was changing'

Phil Charles, technical manager at Jaguar

Not only is the Gen 3 car narrower, shorter, more powerful and some 50kg lighter than the Gen 2, it now has a front MGU and a new tyre supplier in Hankook, so plenty for engineers and teams to get their heads around to the suspension. It's a very different load transfer through the car, through the suspension, through the wishbones and into the main case.'

It's certainly going to be a fascinating aspect of how teams and drivers use their cars on the wide variety of temporary and semi-permanent venues Formula E uses.

The manufacturers received their single test and development cars from Spark Racing Technologies in May, yet such was the pace of the final races of 2022 (eight races from June to August) that only a modest amount of running was achieved by the end of September.

Group test

A specially arranged group manufacturer test was arranged for mid-September where, among other things, the first fast charging pit stops were trialled and a problem with the cells of the spec RESS are believed to have been investigated further.

The manufacturers now have just two months until the traditional pre-season test in Valencia, and that short time period includes homologation of the cars, which will then be locked in for the first two seasons of the Gen 3 rule set through 2023 and 2024.

With all the brake systems around the regen' now being different, Charles thinks it unlikely any team would be in a position at present to claim all their systems are perfect and they've got their car balance spot on. It's a big learning curve for all involved.

Much of which will inevitably come back to the vehicle dynamics, and how they are adapting to the Hankook rubber, which is so far said to be highly durable.

'It has a low wear rate,' says Charles. 'That's a risk for them coming into that big step up in power, and also not knowing the tracks.

'Formula E is very specific, and the tracks we go to over the course of a season are very different. It can be a car park surface one month, and a street surface the next, it's a real mix of surfaces and they're all very different to a normal racetrack.

With battery cooling less of a concern in the Gen 3 package, aerodynamics have taken on a more familiar form

The Hankook tyres are said to be very durable, but only one compound is allowed and there are multiple track surfaces

'They must have taken a view that they haven't got that data set. They haven't gone and tested because you can't get access to a track. You can't go to New York, have a look and measure that great big shipping area.'

New and improved

It won't just be the power, energy and tyres that will be new and improved for Gen 3 racing. Finally, Formula E will have driveshaft torque sensors fitted, similar to those being used in the Hypercar era of endurance racing, which contribute to the BoP process.

'It's a very different load transfer through the car, through the suspension, through the wishbones and into the main case'

Phil Charles, technical manager at Jaguar

Further technological developments include brake-by-wire, recycled carbon fibre and driveshaft torque sensors, with four-wheel drive on the horizon

The Gen 2 car was introduced for season five (2018) and had better battery capacity than Gen 1. Cooling was an issue though, and played an integral part in the design of the car

Supplied by MagCanica, the sensors are fitted directly onto the driveshaft using a bearing-grade plastic. The torque sensor housing is axially constrained using a groove in the housing that interfaces with a mating feature on the sensor housing.

The system has extensive magnetic shielding, integrated seals and cutting-edge electronics and firmware that achieves 0.25 per cent in-vehicle accuracy. Only DC power needs to be provided, and the measured torque signal is returned over CAN, along with additional diagnostic information.

'In our case, they're going to be used more for what we call 'a tunnel', so they're more a control window for us to work within,' explains Charles. 'It's a slightly different usage, but the technology is proven, and it should work well.

'There's a little bit of integrating required for the extra kit, but they fit nicely towards the outboard end of the driveshaft with a measurement sleeve almost that goes around the centre.'

While the manufacturers work flat out to get their Gen 3 packages ready to be homologated in the first week of November, some are openly talking about

Thoughts on racing without brakes!

The Gen 3's maximum regenerative braking capacity of 600kW means a first for a very long time in a racecar, the rear axle of the Gen 3 will not feature hydraulic brakes at all.

Despite being slightly apprehensive about this prior to his tests in late 2021 and early 2022, Formula E test driver and three times Le Mans winner, Benoit Treluyer, was effusive in his praise for the speed reducing characteristics of the Gen 3 test car.

'It's a really big change in motorsports, without the [rear] brakes and all the things we have to develop in software and things like that, so it's a big work we have.

'I was really impressed because the bite really felt like a normal brake, and I couldn't believe it wasn't at the beginning.

'The good thing is you can use this system very well to handle the car on the brakes and to set up the car, so it's a really interesting development.'

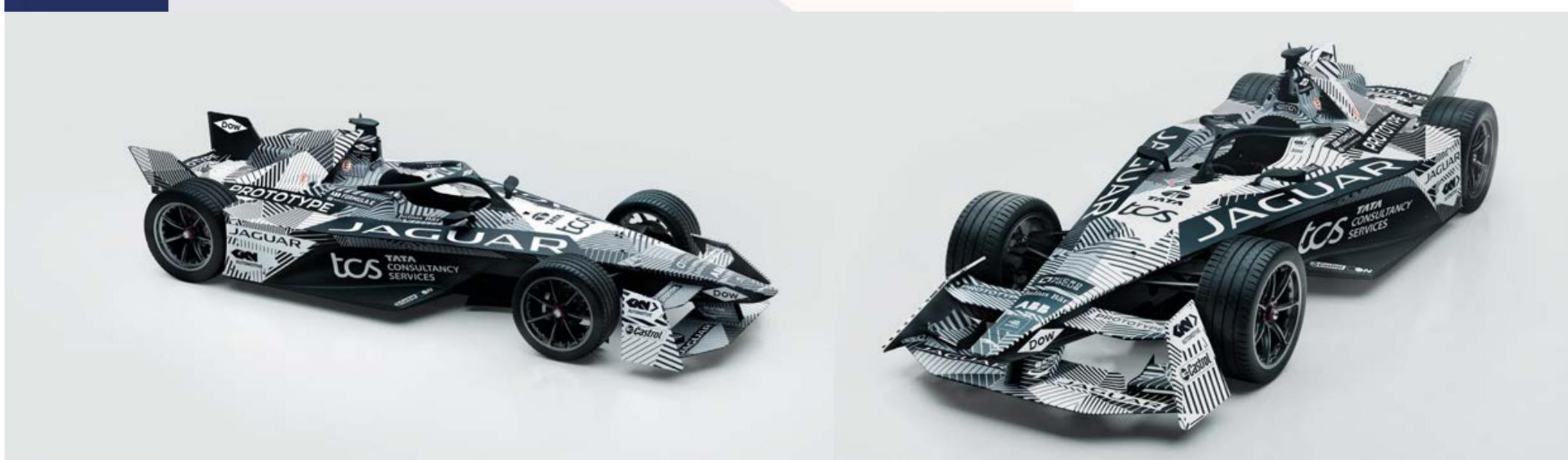
Treluyer then went one better, saying, 'It's actually better than the normal brake, because it's very consistent and it's not like you have to play with the temperatures and set up the cooling, which is really good.'

He then said he felt he could work to a 'new window' in terms of handling.

'In the past in Formula E, the brakes were a bit of a problem to keep in the right window, but this system is actually a really good tool to work with,'

Overall set-up is therefore likely to be even more crucial with the Gen 3 car than it has been in previous generations of Formula E, but again Treluyer was positive about the challenge: 'Every time we've done a small adjustment, the car has answered really well. It's actually very good to drive and to set up.

'And then to enter a corner and control the brakes going into the corner is quite easy if you set the car up really well.'



the possibility of developing an evolutionary package for the final two seasons of the forthcoming rule set, 2025 and 2026.

The FIA is known to have evaluated the possibility of a Gen 3 evo model to run in full four-wheel-drive spec, but a decision is not expected to be taken until the summer of 2023 at the earliest.

The front MGU is said to be entirely capable of being used for traction purposes, as well as regenerative, but further studies of thermal considerations are likely to be needed before achieving a 4WD possibility for the second half of Gen 3.

Environmental impact

The sustainability credentials of the Gen 3 will also see Formula E go up a notch with responsibly sourced minerals contributing to the RESS, while the battery cells are set to be re-used and recycled.

Materials such as linen and recycled carbon fibre will also be used for the first time in single-seater bodywork construction, with the cars featuring recycled carbon fibre from retired Gen 2 cars. This, says Formula E, 'will reduce the carbon footprint of the production of the Gen 3 bodywork by more than 10 per cent. All waste carbon fibre will be re-used for new applications through adoption of an innovative process from the aviation industry.'

Meanwhile, natural rubber and recycled fibres will make up 26 per cent of the Hankook tyres, all of which will be recycled after racing.

The carbon footprint of the Gen 3 car has been measured from the design phase to inform all measures taken to reduce its environmental impact, while all unavoidable emissions will be offset as part of Formula E's net zero carbon commitment.

Backing this up, all Gen 3 suppliers are to operate in line with ISO 14001, the international standard to reduce the environmental impacts of manufacturing, and must also be FIA Environmental Accreditation 3-Star rated.

It's clear Formula E isn't sitting still, very far from it, and now it's down to time to see how well teams and drivers get to grips with the series' latest generation racer.

There's already talk of a Gen 3 evo model, with 4WD a very real possibility, but a final decision won't be made until 2023

The carbon footprint of the Gen 3 car has been measured from the design phase to inform all measures taken to reduce its environmental impact

The challenges ahead for WAE

In pitching for the battery supply deal for the Gen 3 car, Williams Advanced Engineering (WAE) had to take on board a large number of criteria, not least the ability of its RESS (rechargeable energy storage system) to be fast charged.

'They've had to pick a cell type, believed to be initially Total SAFT derived, and a cooling system that can facilitate a 600kW charge rate, in addition to a lot of additional regen' via the front axle,' notes Phil Charles, technical manager at Jaguar.

Last year's Gen 2 Formula E saw a certain amount of energy being regenerated on one axle, but on Gen 3 there's a much higher regen' cycle, and two axles' worth of energy coming in. That means the battery has a much harder cycle to deal with, yet it is 100kg lighter than its predecessor.

The pouch-type cell that has been chosen therefore has to deal with a higher charge rate, and a really high duty cycle that the new car's cooling system is built around. This means very different thermal properties for the teams to deal with, and the possibility that batteries will actually have to be heated up to suit a preferential usage window, believed to be somewhere between 45 and 65degC.

This is essentially opposite to the situation that occurred with the previous McLaren Applied-derived battery, which was started from a very cool temperature.

'Of course, when you put an energy through something, the thermal cycle is key, it's not infinite,' continues Charles. 'But you can make something with a super heavy metallic mass, and it can be thermally very easy. We don't because we've asked for a lightweight battery, all that charge rate and all those characteristics. So it will, by nature, have a thermal operating window. As a team, we've got to work around that.

'We're getting used to that in testing, used to getting up to temperature. The way you go about it is with a pump cycle, blanking and taking into account the cycle you're going to use within the race. That's all part of this process we're in now and learning about.'

Testing has also thrown up some reliability concerns, with several manufacturers having private days curtailed due to suspected cell-derived issues.

This caused Porsche's head of factory motorsport, Florian Modlinger, to openly query the reliability of the spec parts supplied to the manufacturer: 'The FIA is working hard with the common part supplier (WAE via Spark) to find solutions for the topics, which need to be sorted before the first race,' he commented.

'This is an ongoing process. From the current test we are putting a lot of mileage on the car with obviously some compromises in running for the above-mentioned reasons.'

Photos: XPB

The harmony of systems

Racecar talks to Matt Harman, technical director at Alpine F1, to gain an insight into team operations and the development of the A522

By STEWART MITCHELL

At time of writing, the Alpine F1 team and its A522 challenger were in fourth place in the Constructor's Championship, behind Red Bull Racing, Ferrari and Mercedes

'In 2019, when we took the first pen to paper for the 2022 car, the initial intent of the project was to ensure we maintain maximum aerodynamic freedom'

Matt Harman, technical director at Alpine F1

Alpine F1 team technical director, Matt Harman, spent much of his career designing F1 power units, undoubtedly influencing his engineering philosophy with the new car

The Alpine F1 team is one of only a few complete 'works' constructors remaining in Formula 1 – meaning it produces both the chassis *and* power unit for its 2022 contender, the A522, as an official team of the car manufacturer, Alpine (Renault Group). Being a works team *should* mean less compromise on some design elements of the car and better systems integration of the power unit and the chassis. But how does it work in practice?

Matt Harman oversees Alpine's technical group, and 2022 marks his first year in this role. Before becoming technical director, Harman spent half of his Formula 1 career to date designing power units and the other half developing chassis, making him well positioned to recognise the compromises and trade-offs needed to build a competitive car.

Racecar Engineering sat down with Harman at the British Grand Prix to find out a bit more about team operations and how the A522 was developed.

Harman says his philosophy as a technical director revolves around the harmony of systems, particularly in areas like powertrain integration.

'Certain technical avenues on paper are faster because they improve the output in units of kilowatts but, once you've added up all the parasitic losses and considered driveability, we could end up with something that's not actually quicker,' he explains.

'Over the years, I've taken responsibility for many different areas of the car and gained quite a lot of understanding of the car's sensitivities. As a technical director, I think the most important thing is to be able to guide our talented engineers and make tough decisions on which sensitivities to focus on.'

Design process

Despite the deep technical understanding current F1 teams have of the physics at play on the track, the 2022 Formula 1 grid hadn't seen the convergence some expected at the start of this era. In terms of chassis design and packaging, there are several schools of thought on show throughout the paddock, with no two cars following the same path.

Mercedes opted for a narrow-body solution, while Ferrari went for a larger, flat-sided body car. On the other hand, Red Bull, Alfa Romeo, Aston Martin, AlphaTauri and Haas all have a deep, sculpted lower sidepod, while Williams and McLaren went in another direction.

The Alpine A522 is different again, entering at the start of the season with a body design unlike any of its colleagues.

'In 2019, when we took the first pen to paper for the 2022 car, the initial intent of the project was to ensure we maintain maximum aerodynamic freedom,' says Harman. 'This was for two reasons: to maintain scope for our aerodynamicists to manipulate the car to be more performant in some ways for some tracks, and cost optimisation.

'If you need to re-layout your car every time you want to change the bodywork, that's a costly and risky thing to do in a racecar. So at the moment, we've got an excellent mechanical package, which allows us to change the body and go to any extreme without needing to change the position of any underlying systems.

'Through the season so far, we've changed very little under the bodywork, which facilitates us making quite big changes to the car quickly and getting them to a circuit.'

Indeed, Alpine brought a massive body upgrade to the British GP, a significant departure from the one it raced in the season's first half.

To enable such dramatic change, homologated elements such as the side impact structure position needed to be designed to accommodate the different bodies the car might adopt as it evolves, while at the same time not leaving the team vulnerable to having a non-optimised car.

'The lower side impact structure is an area we often discuss when designing a racecar from scratch,' says Harman. 'It sets a reference point for an awful lot of development, and we've got a particular innovation on our car that allows us to manage that quite nicely, which I won't go into too much detail on. That's an area of the car we've worked incredibly hard to ensure we positioned it correctly.

'There was a great collaboration with our aerodynamicists and mechanical teams because it's always a discussion around the chassis structure, the mass and the aerodynamic gain. In this particular car, we challenged the structural people because we needed to make sure the aerodynamicists had the freedom they require.'

'At the moment, we've got an excellent mechanical package, which allows us to change the body and go to any extreme without needing to change the position of any underlying systems'

Structural approach

Alpine heavily explored the stiffness of various chassis and floor sections during the car's development as it is a characteristic that hugely influences the behaviour of parts throughout the operating range.

'It has been part of the discussion that in some cars cause porpoising,' highlights Harman. 'It's understood that there's not a set-up option for most cars to eliminate the porpoising phenomena, so it needs to be structurally and aerodynamically approached.

'Early in running the A522, we decided to focus on stiffness in specific areas. This is for several reasons, one being the

The beam wing has a strong influence on the diffuser. The rear wing, beam wing and diffuser are only powerful in the current aerodynamic regime when they work in harmony

Photos: XPB

Due to changes in regulation with regard to ground effect floors, Alpine's front wing now plays more of a flow conditioning role in ordering the flow field towards the front of the floor

risk of porpoising, and another due to correlation. We want to ensure a good correlation between our CFD, the wind tunnel and the live car on the circuit.

'We maintain that, and we've got to a point now where we understand stiffness for the features that can cause porpoising issues, and understand where to run our car optimally to stay away from it.

'Porpoising is now such a minor issue that it's not something we even talk about too much in our engineering discussions. Our discussions are more about ground clearance and heave movement [so-called bouncing] and ensuring we run the car in a performant manner. I think we've understood porpoising, and we will continue to develop stiffness locally where it's needed to put it into the most performant condition. In the areas where we can be less stiff, we will dial it in to take weight out.'

The power of wings

The 2022 regulations see a much higher performance weighting on the car's ground effect floor, which changes the wings' reliance and role. Alpine's front wing, in particular, has a flow conditioning role in ordering the flow field towards the front floor, which was not part of the previous generation's wing.

'It's fair to say the front wing isn't the dominant force it used to be,' says Harman. 'Once you've got a good one, it's not an area where we spend huge amounts on development. You will notice throughout the paddock that teams are not sending new front wings to every other race, or every three races, like maybe we would have done in the past.'

The rear wing, however, is a different story. 'We need several rear wings for different configurations of racetrack through the year, but also different wings that change the interaction with the beam wing. You'll notice we went for a biplane-style design beam wing, and we have a number of those that complement the main rear wing elements and the interaction with the diffuser.

'The beam wing is a massive player in how we position our diffuser's performance. The rear wing, the beam wing and the diffuser are only powerful together. There's always a lot of discussion around the aero level configuration of each across the operating range because we can only have a finite number of options for them, so we need to be very careful about what we do here. It's made us more mindful with our engineering discussions and car development in this region.'

Weight watchers

In 2022, the minimum weight of a Formula 1 car is 798kg. This is the car's mass with the driver, fitted with dry-weather tyres but without fuel.

The A522 is degined to allow significant changes to be made to the body without needing to alter the position of underlying systems

The limit for car plus driver increased from 752kg in 2021 to reflect the change to 18in wheels and the introduction of new safety features in the chassis.

However, despite the increase, teams found it hard to get down to the limit, even after an increase was implemented to make it less important for them to devote additional funds to weight saving programmes.

'The first thing to point out is that the original weight limit was a guess on the effect the changes to the chassis and the new wheels would mean on the scales,' says Harman. 'Several technical people consulted on the number at first, and we made an initial guess.

'I think where we've ended up is in a position where, realistically, with the changes to the safety regulations and some of the homologated equipment we have to put on the car, that it needed to evolve as we move through the project.

'The more we understood the difficulties of creating those structures, the more we needed to increase our weight. As time goes on, that weight limit will be able to return to where it was in the previous generation, or even go lower.

'We are rapidly approaching the limit today, so I think we'll see that lower limit reached up and down the grid by the end of the season.'

Power unit evolution

Formula 1 brought in the hybrid power unit regime to generate a much more efficient racecar. Initially, the regulations did not stipulate the minimum fuel load, and teams developed internal combustion engines to use the least amount of fuel to start the race with the lightest car.

However, this has since changed, and a mandated 110kg of fuel is now onboard every car on the starting grid. Some teams in the paddock felt this was a backwards step for the efficiency drive, but it did bring more competitiveness throughout the field for those without the resources to exploit the potential of that regime.

'Without a minimum fuel load, it drove us to work on some particular elements to chase efficiencies within the engine and the surrounding systems you run it with,' explains Harman. 'Parasitic losses in a racecar are something we always try to minimise but, when you run a fixed fuel load, the emphasis on that is much greater. We've focused on heat rejection, parasitic losses of heat rejection and things like friction within the engine and round-trip losses.

'With the drive for very high percentage internal combustion engine efficiency, you also need to minimise the losses you achieve on the energy storage system in terms of round-trip efficiency.

Photos: Alpine

Despite 2022 being the ninth year of the 1.6-litre V6 turbo hybrid regulations, the internal combustion engine still leaves the most opportunity for power unit development in the current regime

During the power unit development programme for the 2022 season, Alpine focussed its development attention primarily on heat rejection, parasitic losses, friction within the engine and round-trip losses

'The round-trip efficiencies of this equipment have increased greatly over this era, and the regime we're in now drives that. We've understood fluid technologies and we've understood particular inefficiencies and heat rejection capabilities and how you lay them out in the car. They all have an influence.'

Calorific value

When the energy-limited formula came into place in 2014 and research into the fuel started, Formula 1 fuel manufacturers discovered that some fuel molecules produce significantly more energy than others.

'Without a minimum fuel load, it drove us to work on some particular elements to chase efficiencies within the engine and the surrounding systems you run it with'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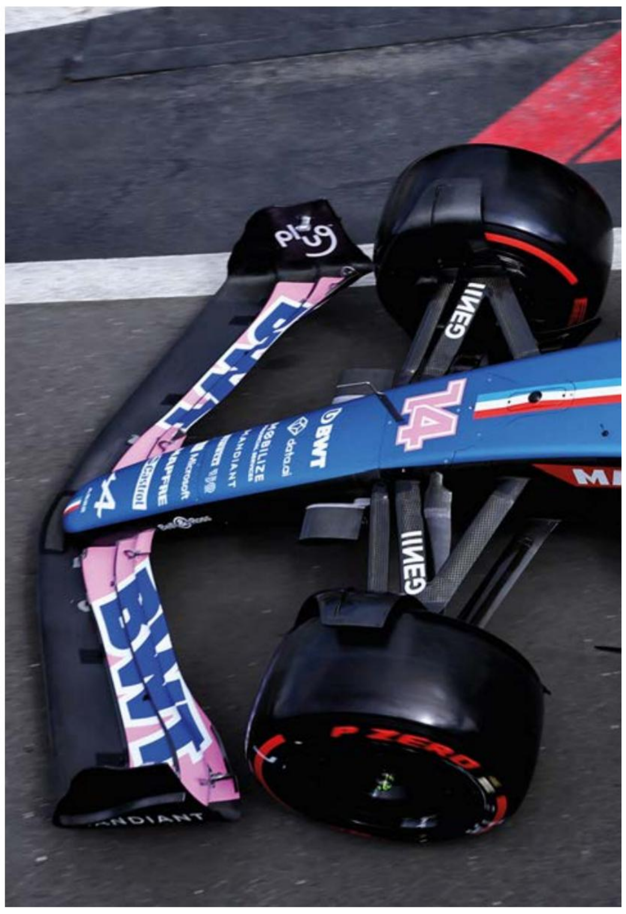


The A522 features pushrod suspension on the front, pull rod at the rear, in line with the car's aerodynamic philosophy

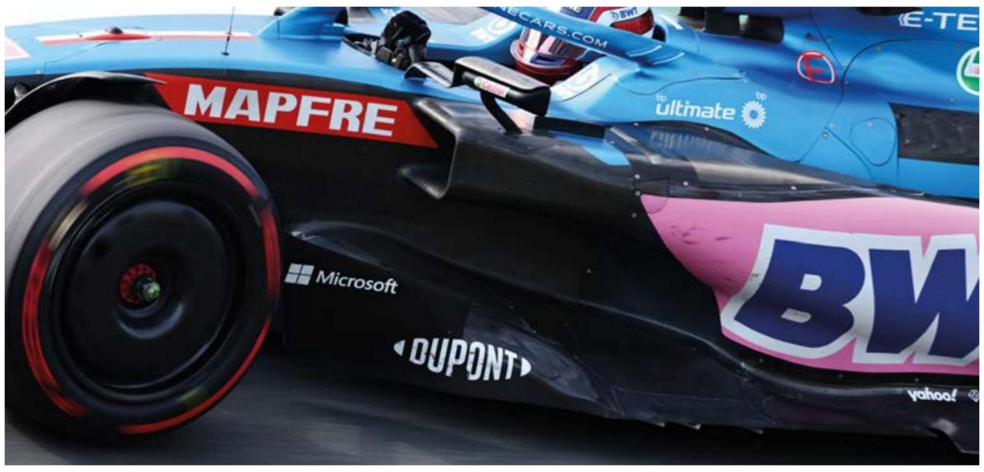
Because the fuel flow and load are prescribed in kilogrammes, there is scope for developing the calorific value of the fuel.

The development targets are how engineers can apply as much energy into one kilogramme of fuel and generate the proper pressure and motion for the direct-injected petrol engine. The research octane number (RON), which ranks how close to the most efficient moment the spark plug can ignite the fuel, is a primary driver in the combustion development of the high-efficiency fuel.

Formula 1 introduced new E10 fuel regulations for 2022 (petrol, with a 10 per cent ethanol content). The construction of the ethanol molecule means it carries a lower quantity of joules per kilogramme as a combustible vapour than the equivalent volume of race fuel.

Regarding the effect this had on the Renault E-Tech RE22 (the Alpine A522's PU), Harman notes: 'Thanks to the work by BP Castrol, we haven't allowed the lower calorific value of the ethanol to impact us. We have done a great deal of development in this area and adjusted the power unit to suit the particular E10 fuel. I can honestly say the actual difference from that fuel is unmeasurable.'

As per all alcohol-based compounds, ethanol's evaporation characteristics mean it will extract temperature out of the combustion chamber during the intake and compression strokes and initial stages of combustion.



The square sidepod intake was an in-season upgrade to make more of the scope of this entry. Previously, it had a curved outer surface

The lower vapour pressure and temperature can also take away some of the heat rejection requirements of the engine.

'However we're not seeing much of that heat rejection benefit because we push the fuel to the limit,' says Harman. 'The main difficulty we have had with the E10 fuel is the ability to pump it at temperature. We have to do some management of that, though it's what we do in a racecar anyway because, even if we had a different vapour pressure, we'd still have it on the limit.'

The ethanol lets the mapping engineers lower the ignition advance, taking it closer to TDC and initiating better timed combustion. The design engineers can adjust several follow-on configuration parameters from

'Thanks to the work by BP Castrol, we haven't allowed the lower calorific value of the ethanol to impact us. We have done a great deal of development in this area and adjusted the power unit to suit the particular E10 fuel'

Photos: XPB

There is an exit flow condition positioned midway down the A522's floor, which rolls a vortex of air that isn't attached to the tunnel flow under the car. Slots further back on the floor edge re-ingest some of the exit flow to work the diffuser

The A522's post-Silverstone sidepod design features a deep sculped section under the sidepod to leave space for the upper floor surface to interact with the underfloor flows and other aerodynamic furniture at the rear of the car

these characteristics, such as the compression ratio (if under the 18:1 limit within the rules), which could increase combustion efficiency.

Moreover, ethanol molecules contain oxygen so, instead of solely relying on the oxygen ingested into the engine through the intake, further oxygenation of the working fluids in the combustion chamber occurs. It's also allowed engineers to optimise the enthalpy loop through the turbine because it will no longer have the same target of kilogrammes per hour of oxygen from ingested air.

'The internal combustion engine still leaves the most opportunity for power unit development in the current regime,' highlights Harman. 'There's still a lot more efficiency to be had from these IC units from the thermodynamics side, but also some of the basics we can exploit – friction and things like that.

'As we've amassed more and more knowledge into the engines, we can take a step forward in those areas, too. There's still a great deal to be learned in the energy recovery system, particularly in battery technology, which is moving forward quickly. Although that area is broadly homologated, how you manage those batteries in terms of energy strategy and thermal management is still a huge development area in these power units.

Renault's F1 power units have seen various different battery types, capacities and configurations over the years, but more recently the technologies of those that can supply the power densities needed for a Formula 1 racecar have converged throughout the paddock.

'We've converged to the optimum for us in terms of configuration,' says Harman. 'We're pretty happy with the configuration we have, though you've got to make sure you can thermally manage it in all different racing scenarios as that's critical to its performance, power output and durability.'

Battery technology

The Renault E-Tech RE22 battery uses cylindrical-type cells that can be discharged and charged quickly and cooled efficiently, thanks to their architecture.

'The cells we've selected demonstrate a very high power-to-weight ratio and power density,' highlights Harman. 'Being cylindrical, they are much easier to cool and a much easier mechanical solution to package when compared to pouch or prism cells. This is why batteries in the F1 space have this form factor.'

The Alpine F1 team and its A522 challenger are obviously doing something right. It's proven to be a force to be reckoned with in the 2022 Formula 1 season to date and, at time of writing, stood in fourth place in the Constructors' Championship behind Red Bull Racing, Ferrari and Mercedes.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Differing perspectives on raceability, with regard to the BoP process

By SCOTT RAYMOND

In the last article about the BoP process, we discussed the concept of raceability, or the ability of cars in the same class to race each other. We saw how a sanctioning body (the FIA) proactively promotes raceability with defined performance targets in the homologation regulations, and reactively addresses raceability with Balance of Performance. That said, sanctioning bodies are not the ones who invest huge quantities of money to put racecars on track and vie for race wins and championships.

So, let's look at raceability through the lens of some other stakeholders who, arguably, have more to lose if the issue is not properly addressed – manufacturers and teams.

To understand how manufacturers address the topic of raceability, I spoke with the person responsible for BoP management at BMW Motorsport, Mehdi Ahmadi. The team perspective was gleaned from Ricky Taylor, driver of the no.10 Acura DPi for Wayne Taylor Racing in the IMSA WeatherTech SportsCar Championship.

In this article, we'll examine their responses to some questions about raceability, while I provide my thoughts on each response from the perspective of someone who does the BoP process for a sanctioning body.

The first group of questions are targeted towards what a sanctioning body can do with regulations and BoP adjustments to evaluate and improve raceability. Something interesting I realised better after reviewing the responses is that there are two distinct phases of the BoP process – car design, and between race. The point here is that one cannot do anything about the car design phase once the car is homologated and produced, one can only use the available adjustment parameters in the between race phase to try and influence raceability.

Hoch Zwei

Raceability and the BoP process

Q Do you feel current BoP processes adequately address the issue of raceability?

Mehdi Ahmadi (MA), manufacturer: *Raceability, as you have defined it, in my view cannot be addressed in principle by the BoP process since the main goal is to level the performance of cars with different design philosophies and performance. This is achieved mainly by weight, power, aerodynamics etc, which places cars within a small performance window.*

Depending on BoP adjustments and car concepts, it is always possible that a car's strength could be in cornering or, conversely, in top speed. These strengths give an advantage to a brand in terms of passing depending on the circuit. Further set-up and aero adjustments might help and improve it when possible.

Ricky Taylor (RT), driver: *I would say it is somewhat the responsibility of the constructors / manufacturers to build a car that races well. However, when you think of motorsport as a show, that should place some responsibility on the sanctioning body, or rule set, to encourage more exciting racing for the show.*

Whether it was IndyCar's Hanford device, or Formula 1 with the big front wings, sanctioning bodies seem to have placed some emphasis on improving raceability to better the show, while some series use crutches to improve the racing show without changing the design of the cars, whether it is DRS or push-to-pass.

Scott Raymond (SR): Both responses are quite interesting, and it's important to remind readers that the BoP process is not only data analysis and decision making between races, but a process that includes the homologation regulations, which define the design of a car.

I say this as both answers lean towards car design as being more important. Most tend to think BoP is only changes made between races. This goes back to the FIA's Nicolas Aubourg talking about performance windows that cars must fall into before they can be approved for homologation.

From a manufacturer's perspective, Mehdi is effectively saying that the between race BoP process cannot, or perhaps should not, address raceability. Rather, it should be addressed with the performance windows, leaving it up to the teams to adjust a vehicle's set-up to improve raceability.

Ricky's driver's viewpoint aligns with the idea that a car should be designed with raceability in mind, but he brings up a critical point: motor racing is primarily an entertainment and marketing industry. This is one of the main things that motivates me to try and do the best job I can with respect to the between race BoP process and car adjustments.

Manufacturers, teams and race fans are the customers of a sanctioning body and, if the racing is not good enough, or not balanced enough, you will have a lot of unhappy customers. But, if raceability is best addressed by the car design phase of the BoP process, what scope does that provide a person like myself to make an improvement?

SRO / TWENTY-ONE CREATION - Jules Benichou

Motor racing is primarily entertainment, so raceability becomes a more complex factor than just making cars easier to drive, it's about having cars that race well together, and put on a good show

Q ***What do you think sanctioning bodies could do differently to better address the concept of raceability as part of their BoP processes?***

MA: *In my view, performance separation between classes is the key here. When the class separation is not big enough, the situation gets complicated within each class and overall.*

RT: *In prototypes, the main struggle we have is how closely we can follow other cars. But some cars follow better than others and some cars are harder to follow than others. I don't feel that the raceability of various cars should be balanced, but rather the rules, or homologation, should make the cars easier to follow.*

However, the rules should still allow teams and constructors / manufacturers freedom to design what they want. Again, I reference the larger front wings in F1 a few years ago.

As a driver, if you are faster than the car ahead, you should be able to follow closer to set up a pass. With the current prototypes, at certain tracks the amount of time lost in traffic is far too great, so making the whole field of prototypes more raceable would be a great improvement.

That said, I don't think a drafting device to keep cars closer is a good solution because it brings the people who are not doing as good a job up and allows people to be in the race that should have been lapped by the car in front.

SR: Mehdi's point here is very valid and, while it may not seem so, Ricky's response addresses the same issue Mehdi brings up. It is important to remember that BoP is not just about cars in the same class, but can encompass cars in different classes racing on track at the same time. Given this, it is critical to ensure the general performance of the cars in different classes is disparate enough that they don't drastically interfere with each other when racing.

This is a big part of what Ricky is saying about dealing with traffic. When the cars in different classes are too close on performance, bad things can happen because drivers in the faster cars take bigger risks to get through traffic, which can cause a lot of yellow flags.

Q ***With respect to parameters that are adjustable as a part of a BoP process, which do you feel are most important when addressing the concept of raceability?***

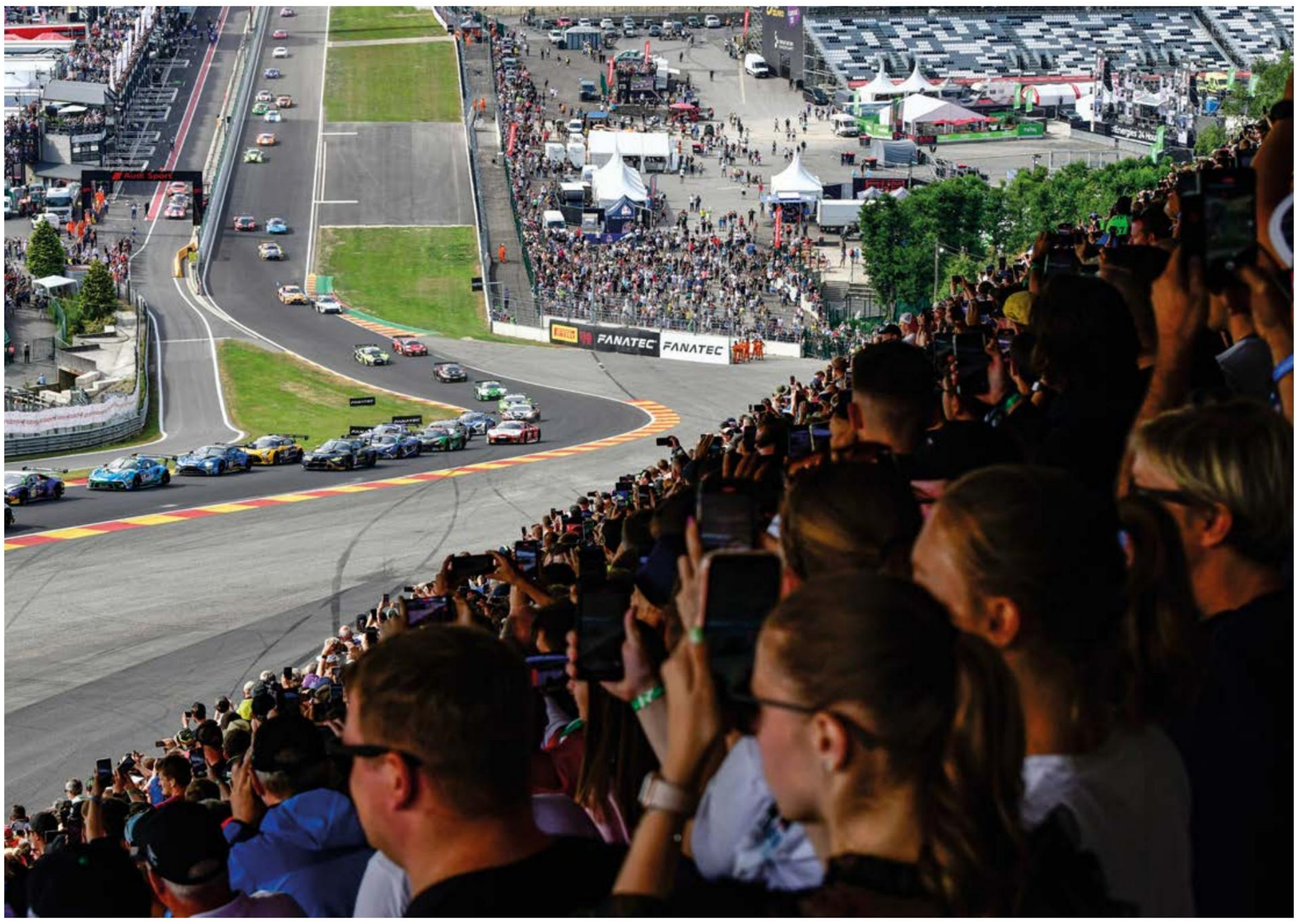
MA: *Drag and engine power.*

RT: *Just the ability to follow closely.*

SR: Short and to the point. Mehdi's answer points to both the between race BoP process and the car design BoP process. Performance windows hopefully get everyone close at the beginning, and small adjustments can then be made to address any concerns once the cars are racing.

Ricky's answer goes back to the car design BoP process as, apart from drag-reducing parts implemented by a sanctioning body, following closely is something that must be addressed by the homologation regulations for the cars.

SRO/Jules Beaumont



The trick is to balance entertainment with genuine racing, as nobody wants to pay to watch a procession with an obvious outcome. Manufacturers and teams therefore need freedom to develop

XPB

In all forms of motorsport, traffic is the big decider. Designing a racecar to handle that unpredictable element successfully will inherently improve its raceability. Torque is your friend here

Raceability and car design

These next questions focus on raceability from the manufacturer or car perspective, so are not as pertinent to the BoP process. However, I wanted to investigate these topics to understand a little more about whether raceability is being considered with respect to the design philosophies for vehicles.

Q How much does the concept of raceability influence the design of a car?

MA: *Actually, not enough, because any particular advantage you might try to build into the design will be capped by the BoP process.*

RT: *I'm not a car designer, but as a driver you want a car that can rely on mechanical grip, or not rely so heavily on downforce to make its grip. If the car has strong mechanical grip, we can follow relatively closer when in the wake of another car. In prototype and sportscar racing we do not have any as-designed or in-car devices to improve the car's raceability, but that might be because we have an organic factor that improves racing as a show, which is the traffic. Traffic allows the race to be condensed and puts prototypes in a position where they can overtake regardless of how poorly two of them may otherwise race on the track together.*

SR: I fully appreciate Mehdi's point here. One reality of BoP racing is that the best designed car is not always the fastest racecar. This point is always brought up by detractors of the BoP process.

But, as I have pointed out before, BoP is a necessity in today's financial environment. We need to make sure manufacturers don't spend themselves into oblivion, and we need to make sure there is a variety of vehicles participating. This does mean sometimes the best design is not the best car.

That said, I have seen some evidence of changing design philosophies from some manufacturers over the years that I have been working in performance balancing.

In particular, I have observed a trend where GT manufacturers design cars and aerodynamic packages that lean towards higher downforce. This means the cars have more drag and therefore require more engine power to overcome the speed losses induced by drag.

With the performance windows set out by the FIA, the maximum power output will be limited, but the torque and power output at lower engine speeds can by increased. Increased torque tends to improve the ability to work through traffic and pass slower cars.

Ricky's point about the organic nature of traffic is spot on. As such, designing a car to handle traffic will inherently improve its raceability.

Q What techniques or design characteristics can you use to improve the raceability of a car?

MA: *Improved component reliability plays a big part as it means cars can mix it with other categories and withstand impacts.*

RT: *The car needs to have good mechanical grip, or some method to maintain downforce when behind another car. More specifically, we need a strong front in high-speed corners, and good braking power and traction to get out of the corner.*

Putting half of the car in clean air is the most common technique when following another prototype. However, that is often putting you at the mercy of the lead car and putting your car on a less ideal racing line.

What if there was a movable aero device, like DRS, but instead of trimming the rear on the straights we could add front downforce in corners? That would be cool. You don't have to use that, but it'd be pretty neat!

SR: I had to leave Ricky's final comment in there, and not just because it cracks me up, but because it presents an interesting concept to consider. Current solutions such as DRS *do* improve the ability to pass cars on straights but, in many cases, following another car takes away aerodynamic grip from the front end of a car. This makes it difficult to pass because the balance shifts to too much understeer.

Mehdi's comment also made me smile, not least because Mehdi is typically a very serious guy, so his comment is made in all seriousness. What I find funny is that Mehdi is basically saying that sometimes the best way to pass another car is to push it out of the way!

He is directly addressing the fact that racing is a contact sport, and that cars must be designed robustly enough that they don't fall apart when rubbing wheels or bodywork with another car.

I worked on a car in the past with flimsy dive planes, and any time we had light contact the dive plane would break and the aero balance was completely screwed up. Needless to say, the next iteration of that car had dive planes you could stand on without breaking.

Q Do you think designing for raceability is more important for a prototype than a GT car?

MA: *Yes, absolutely.*

RT: *I think GT cars are already much better, in terms of raceability, than prototypes, simply because they rely less on aerodynamic grip from the car and can maintain good pace when following another car closely.*

SR: I find Mehdi's comment here intriguing, given BMW races GT3 cars and will have an LMDh prototype next year. There's nothing to read into it, but I think it speaks to one of the main points Ricky has made with respect to working with traffic.

Conclusion

I would first like to conclude that Ricky Taylor is not a fan of DRS! Joking aside, I agree that it would be better to address raceability without resorting to gimmicks, but I also very much enjoy watching F1 cars pass each other, as opposed to proceeding around racetracks in a orderly fashion.

The perspectives of a manufacturer and driver provided in this article have highlighted that raceability should be addressed primarily in the design phase. With respect to the BoP process, this means sanctioning bodies should include provisions in the homologation regulations that promote designing for raceability.

But then someone like myself, who works mostly in the between race phase of the BoP process, may not be left with many options to make a difference…

The perspectives of a manufacturer and driver provided in this article have highlighted that raceability should be addressed primarily in the design phase

Richard Dole

Raceability is of particular importance in prototype formulae, where cars rely on aerodynamically-generated grip. GT cars, on the other hand, are generally more capable of racing well together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University's challenge

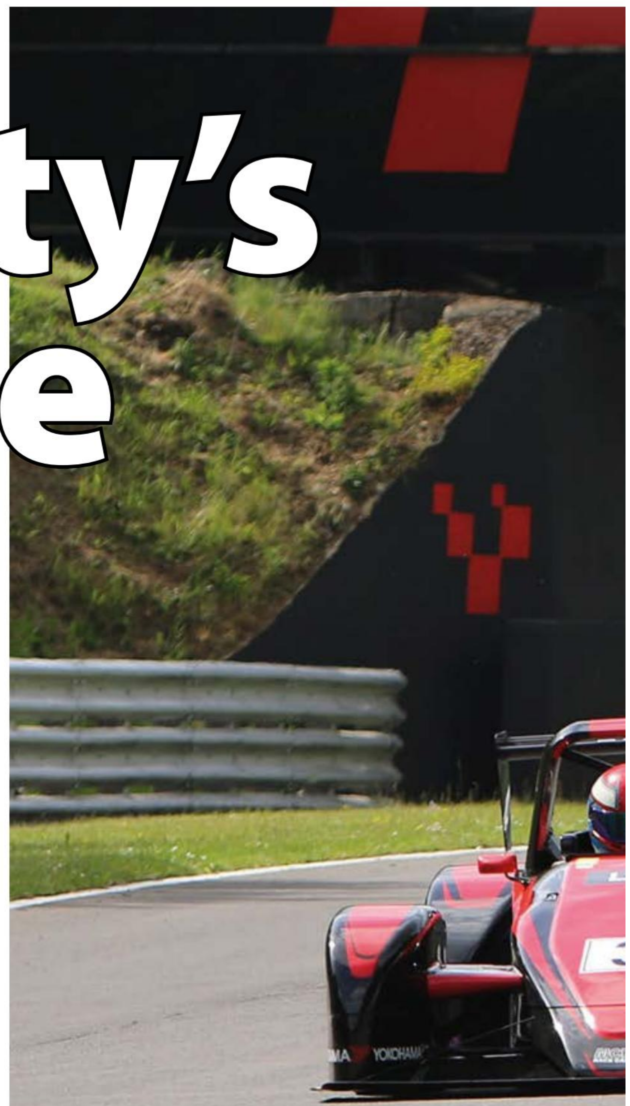
How a tie up with a local university has helped Welsh racecar manufacturer, MCR, transform the aerodynamics on its Sports 2000 challenger

By MIKE BRESLIN

There can be few locations for a racecar constructor that can rival that of Sports 2000 specialist, MCR. Perched on the verdant heights above the lovely little harbour of Solva, just down the road from the achingly picturesque city of St Davids in the very far west of Wales, this company is a long way from the homogenous industrial estates of the UK's Motorsport Valley in every respect.

Yet, while MCR's base might be far from the heart of British motorsport, it's still able to draw on a deep well of technical capability, partly thanks to a tie up with the motorsport engineering course run by the Swansea campus of University of Wales Trinity Saint David, formerly known as Swansea Institute. What's more, through this relationship the Welsh company has managed to transform what was already a highly successful racecar, doubling its downforce with no increase in drag. Which, when it comes to aero development, is about as good as it gets.

The name MCR might be familiar to readers in North and South America, as the original cars, designed by Brazilian Luiz Fernando Cruz, have been campaigned extensively in Sports Prototype racing on both continents. Clive Hayes, managing director of MCR in Wales, first came into



MCR is dominant in Sports 2000 in terms of numbers on the grid and results. Here two of the newly bodied S2Ns are followed by an original S2

CFD study from Trinity St David blended with an on-track image of the MCR S2N. Work by students on the university's motorsport engineering course has transformed the aero on this Sports 2000 racer

Photo: KJG Photography

'I guess the car has been developed over the years by informed common sense, if you like, in terms of aero concept'

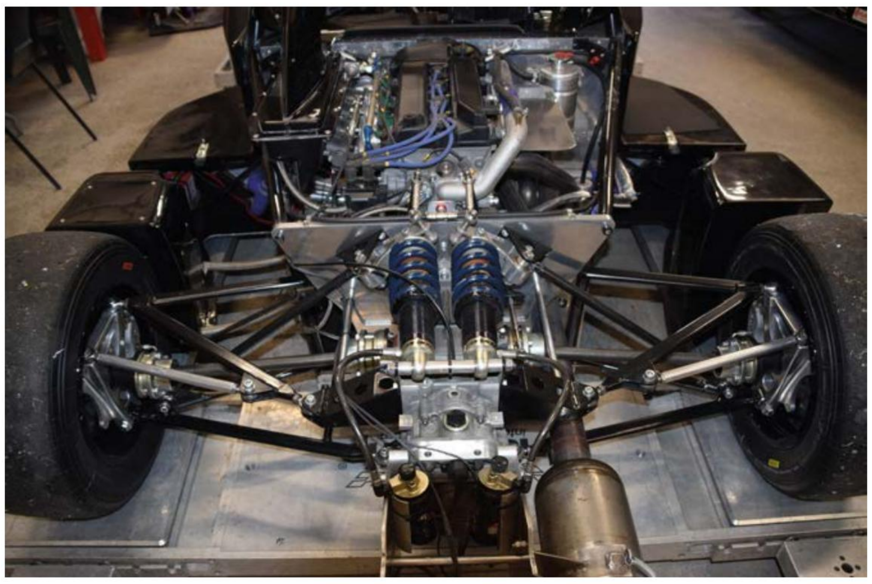
Tim Tudor, senior lecturer in motorsport and automotive engineering at Trinity St David

contact with the cars in the 2000s, when a friend of his, motorsport paint expert Matt Manderson, imported a couple for the pair of them to race. Manderson then stepped back from Sports 2000 due to work commitments in F1, but Hayes went on to order another two MCRs from Brazil himself.

Production rights

'I purchased two cars in kit form,' he confirms, 'but when they arrived, they were in a bit of a mess because the couriers had put a forklift through the pallet, destroying the bodywork and damaging the chassis. So, I rang up and said, look, we can't be having this all the time, I'll just buy the MCR manufacturing rights for the UK and Europe. And that's what I did.'

Hayes is an interesting character. He has been a mechanic, operator of a sightseeing boat and scuba diving centre, and second coxswain of the St Davids lifeboat, amongst other things. But these days he heads MCR full time, working alongside his partner, Cindy Pearce, and Anthony Evans, who runs the bodyshop that's attached to MCR's unpretentious, delightfully old school, race shop.



Modern Sports 2000s are powered by a near standard 2.0-litre, four-cylinder Ford Duratec engine. MCR's gearbox is five-speed sequential, supplied either by Hewland or Sadev, while the car's Penske dampers are pushrod activated

If you're wondering why a race constructor needs its own bodyshop, it's because Sports 2000s have a *lot* of bodywork, and Evans tends to be very busy after hectic races. Hayes is also a race driver, which is how he became involved in Sports 2000 in the first place of course, and a very competent engineer and machinist who is extremely hands on when it comes to racecar production and preparation.

With Hayes at the helm, MCR has become the dominant constructor in Sports 2000, in terms of both the number of cars on the grid and results, winning the championship six times in the last eight years and developing the car year on year so that its S2 became a very different beast from the original Brazilian-built MCR.

The company generally sells between two and four cars a year (they cost £55,000 (approx. $60,725), turnkey) and has made about 26 since it started producing the chassis itself in 2007.

Club racing

The cars are built to the open, though tightly controlled, Sports 2000 regulations. Devised in the 1970s as a Sports Prototype version of Formula Ford 2000, Sports 2000 has been a mainstay of the UK national and club racing scene ever since and now attracts big grids and produces very good racing.

Chassis are spaceframe, although some of the older Ford Pinto-engined class cars use aluminium monocoques. Hayes, though, is a big fan of tube frame cars.

'I can repair a spaceframe chassis easily,' he says. 'Cut bits out, weld bits in and things like that. To fold and pop rivet a monocoque chassis is specialist work and I just haven't got the time to do it.'

Just because they are easier to repair, this certainly does not make the cars less safe than those with monocoques.

'On our cars we actually bond a honeycomb in between the rails of the chassis, so it makes it very stiff and very strong,' confirms Hayes. 'We also have a crash box structure on the front of the car that absorbs impact from head-on collisions. That's part of the regulations, and it does work. We've had a few big incidents where the crash box has absorbed all the impact.'

Durable racing

'It's very rare that we get chassis damage,' Hayes adds. 'We've had wishbone mountings break off under impact, things like that, but that's basically how we've designed it, to come apart and absorb impact, not to just bend the chassis.

'It's like a carbon fibre tub, basically. The structure that you're sitting in is very strong and the bits around it are designed to crumple or break off to absorb all the impact.'

The safety features don't stop there, either.

'The rollbar covers are actually covering two roll hoops,' says Hayes. 'And where the mirror is on the front, that's actually a roll hoop as well, and it's designed so that when you take a measurement from the front roll hoop to the back roll hoop, the driver's head is 50mm below the straight line between them.'

The '2000' in the Sports 2000 title (those involved in the category often call it 'Sports 2'

The car with the old bodywork, here without dive planes, was taken to the MIRA wind tunnel to validate the CFD model

CFD merge of the original car showing the flow over the control rear wing. While this aerodynamic device is not particularly effective, the real issue with Sports 2000 racers is understeer

Photo: KJG Photography

The newly bodied car, now called the MCR S2N, features pontoons over the front wheels and deep channels either side of the nose structure. The splitter is also both longer and wider

Take your foot off the brake

refers to the engine, which is a pretty much standard 2.0-litre Ford Duratec. Though as the manufacturer has now stopped producing these engines, the championship has started to think about switching to another powerplant sometime in the future.

One of the great things about the Duratec, at the risk of a partial pun, is its durability.

'We've got customers with our cars that haven't rebuilt an engine in five or six years,' says Hayes. And while it only gives around 200bhp, in a 530kg car like the MCR, with its slicks and aero, it's good for 46-second laps of Brands Hatch, a second quicker than the British Touring Car Championship.

Transmission is a five-speed sequential, and MCR offers its cars with either Hewland or Sadev units, while suspension is quite conventional, with rocker-activated pushrods on all four corners. Dampers are restricted to two-way adjustable items, though the make is free and MCR uses Penske.

As for electronics, Hayes says: 'We use a Race Technology data logger and dash, and that's about it, really, because there's no fancy traction control or launch control or anything like that allowed. We're not even allowed a flat shifter on the gearchange.'

Hayes says the biggest challenge is getting the car down to the 530kg weight limit, which is partly to do with all the bodywork on a Sports 2000, which tends to be glass fibre – though MCR has offered carbon body kits in the past and is likely to do so again – while the single-element rear wing is composite.

A problem of grip

Which brings us neatly to the aerodynamics. Original Sports 2000 cars, and those that now compete in the Pinto class / championship, were restricted to nothing more than a Gurney on the rear. To differentiate the Duratec cars, these more modern racers run a rear wing, though Hayes says it was basically an aesthetic consideration and is not particularly effective. Yet it's not really the rear of the car that's the problem with Sports 2000, as Hayes explains:

'The regulations stipulate what size wheels and tyres we have to use, and we have six-inch front tyres and wheels and eight inch on the rear. 'Basically, there's not enough grip on the front, so we're always understeering.'

Over the years, MCR added dive planes to the front of the car and tried other remedies, but never fully cured the condition. Which is where Trinity St David came in. Tim Tudor is senior lecturer in motorsport and automotive engineering at the establishment that offers its students a little more than Formula Student experience.

'We did Formula Student for a number of years, but we have migrated away from that because, while we think it's a really good engineering exercise, we're specifically trying to create graduates to go into motorsport jobs, so we want to give them real motorsport experience. That means at circuits, against other professional teams, as opposed to just other student teams.'

The university has a long history in racing, having been involved in British GT when it was set up as the first motorsport engineering course in the UK in its Swansea Institute guise in 1998. These days, it runs a student-staffed, MCR-equipped team in Sports 2000 and has worked closely with Hayes for some years.

Project aero

'We've worked with Clive before on numerous aspects,' confirms Tudor. 'We've had projects looking at suspension kinematics and we've been looking at chassis optimisation through some of our R&D work. But the project I was specifically involved with, with the students, was looking at the aerodynamics of the [Sports 2000] car.

'I guess the car has been developed over the years by informed common sense, if you like, in terms of aero concept. But with the facilities we've got with CFD [it uses Ansys Fluent] and access to wind tunnels, we wanted to do a proper optimisation of it; what could we do to improve the vehicle's aerodynamic performance around the current chassis?'

The project started with a very thorough assessment of the MCR, which involved full-scale wind tunnel tests at MIRA and painstakingly constructing a model in CFD.

'Reverse engineering the original surfaces, for creating the baseline to assess the original design, was challenging,' admits Tudor. 'That took a while in terms of CAD surface and modelling, and capturing those surfaces. We captured the data in a number of ways – we did some manual measurements to get the overall surfaces, but then we also used some 3D scanning, and then created the surfaces from that. But 3D scanning is not a one-button operation, it takes quite a lot of time.'

TECH SPEC: MCR S2N

Chassis
Box tubular spaceframe construction with integral safety cage; anti-intrusion side structures; stressed aluminium alloy panels; rack and pinion steering; aluminium crash box; 45-litre aluminium fuel cell

Bodywork
Multi-piece lightweight and aerodynamically optimised GRP bodywork; front splitter; single-element carbon fibre composite rear wing with adjustable angle

Engine
Ford Duratec 2.0-litre, inline, four-cylinder engine producing approximately 200bhp

Transmission
Hewland or Sadev five-speed sequential gearbox

Suspension
Steel fabricated double wishbones all round; pushrod / rocker-activated Penske coilover dampers; anti-roll bar adjustment mechanism with easy access for changes; ride height, camber and toe settings adjustable for each wheel

Electronics
Race Technology data logger and dash

Brakes
Dual Wilwood master cylinders; Wilwood four-pot aluminium racing calipers front and rear; 255mm vented discs front and rear

Wheels and tyres
OZ magnesium centre-lock wheels, front 6in x 13in; rear 8in x 13in; Yokohama slick tyres

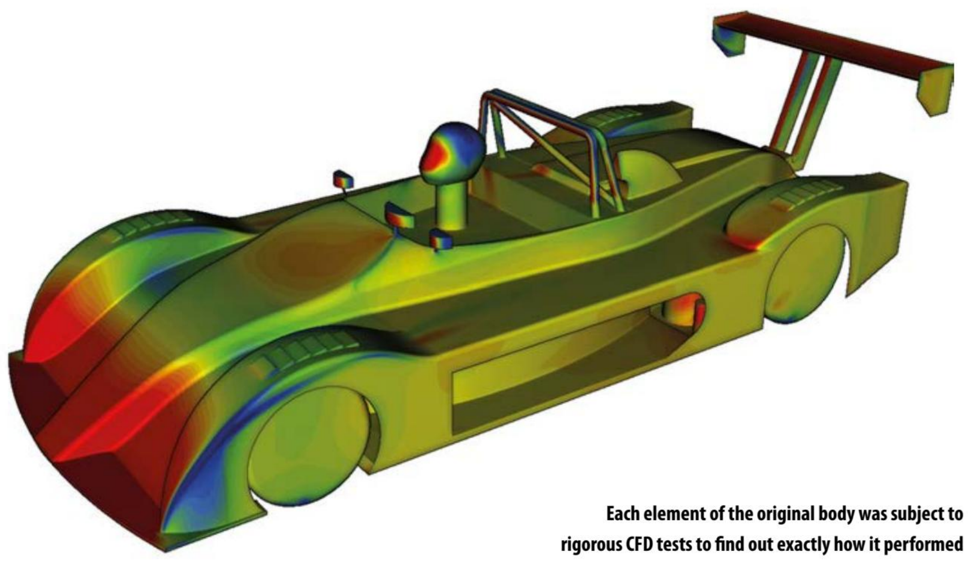
Dimensions
Length (including wing): 4410mm

Width: 1780mm.

Weight: 530kg

Price
£55,000 (turnkey (approx. $60,725 at time of writing)

> **'We wanted to do a proper optimisation of it; what could we do to improve the vehicle's aerodynamic performance around the current chassis?'**
> *Tim Tudor, senior lecturer at Trinity St David*



Each element of the original body was subject to rigorous CFD tests to find out exactly how it performed

Also involved in the project was former Caterham F1 technical director and McLaren, Ferrari, Renault and Jordan head of aerodynamics, John Iley, who, as well as heading up his own consultancy, Iley Design, is professor of practice on the Trinity Saint David motorsport engineering course.

'The students did a full CFD programme, and I was working for an aero development company at the time who had CFD, so we had a second opinion, basically, to verify the results,' he says. 'And then we did the same with the development work, so we had internal and external evaluation of the development path as well.'

Parametric study

After the baseline model was made and verified, second year students undertook what's described as a parametric study.

'We looked at changing lots of different aspects of the bodywork geometry, to find out what effect on the aero performance each of those pieces had,' says Tudor. 'And then we had another final year project that carried that on to look at developing a new concept with all of the understanding and gains from the original project.'

This involved testing around 40 different bodywork configurations in CFD.

'We spent a lot of time going through the evolution of the new bodywork, trying to make sure we could get the balance right, whilst also getting the improvement on overall efficiency,' Tudor adds. 'We actually had limited improvement from our 25th iteration onwards, but that was because we were trying to fine tune the balance rather than produce more downforce.'

The work was split between the students, with about 15 of them involved over the three years the project ran for in total.

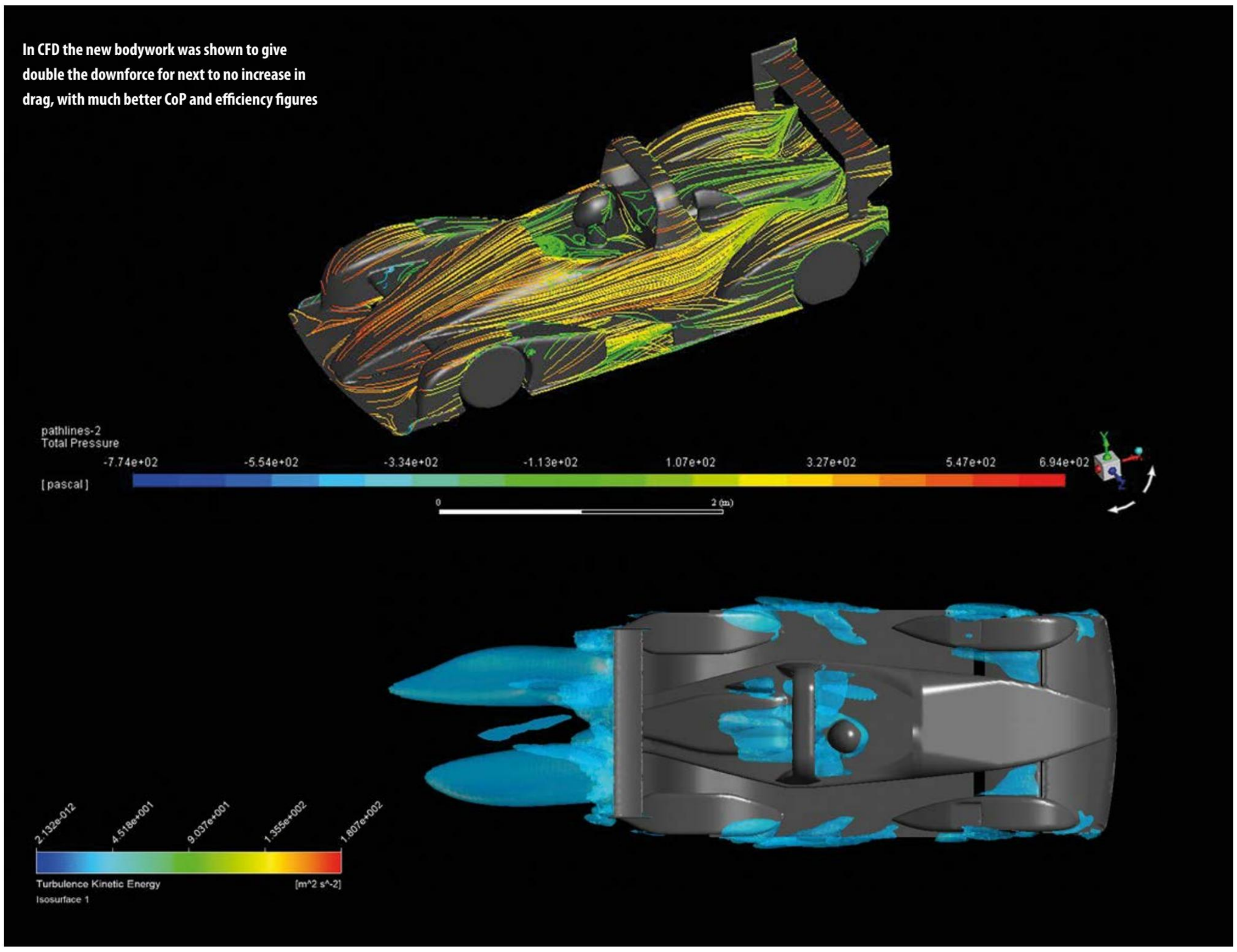
'Each student was given an area of the car, very similar to how it operates in top-level motorsport when you have the resource,' recalls Iley. 'So, someone was doing the cooling, someone was doing the rear wing… The car was divided into six areas. And they couldn't just go off and do what they wanted. They had to liaise and coordinate with the person downstream, or interfacing with their areas.'

Because Sports 2000 is still an open formula and MCR does have competitors on the track and in the marketplace – its main rival is Gunn – some of the technical details and the data to do with this project have to remain secret, but Iley does tell us: 'It's quite difficult on closed wheel sportscars to get the front end working successfully. So, a path sportscars have taken, I would say since probably the late '80s, early '90s, is to get a lot more airflow through the front of the car, to get it to breathe more successfully.

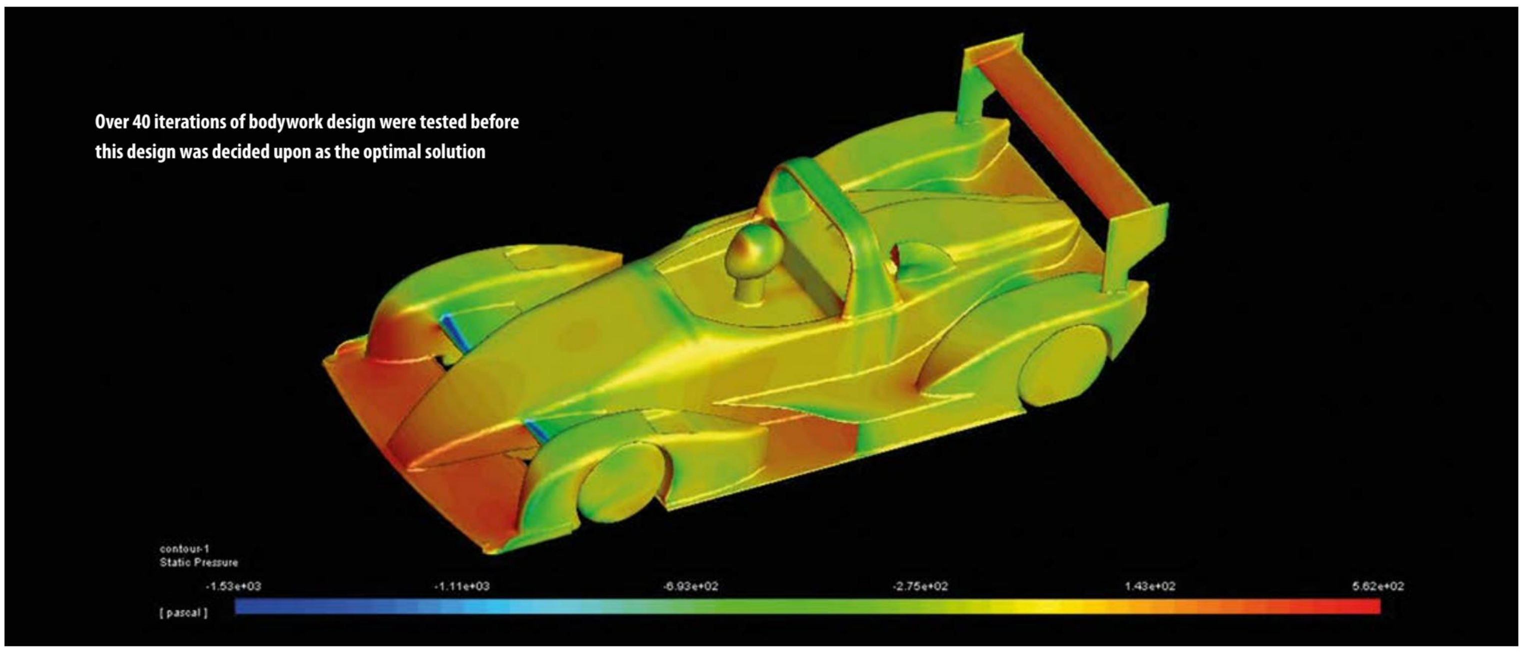
'And yes, that clearly helps a lot in terms of generating overall performance, but particularly front-end performance. So we followed that methodology in order to not just achieve an overall increase, but also to be able to achieve a more workable car balance.'

Body building

The final version of the body looks completely different to the original car, with distinctive pontoons that cover the wheels and wide and deep channels for the airflow either side of the nose, rather than the previous swooping front end.



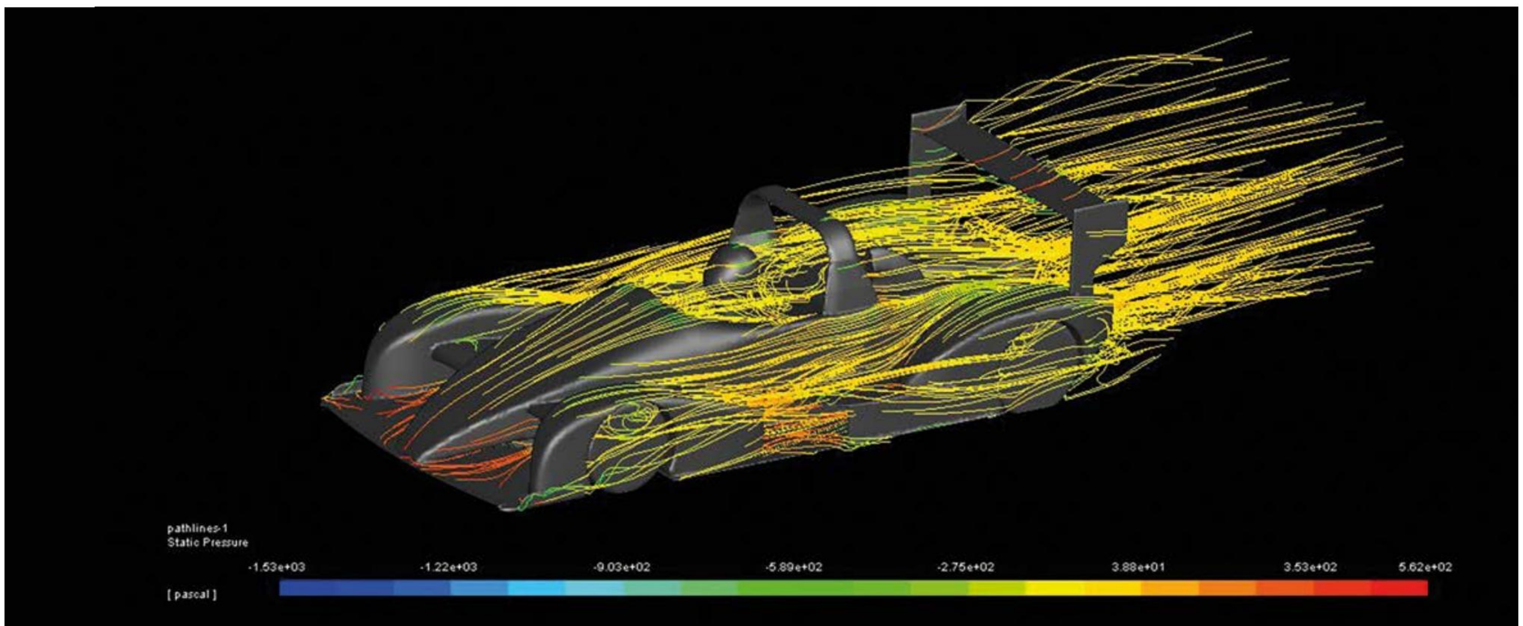
In CFD the new bodywork was shown to give double the downforce for next to no increase in drag, with much better CoP and efficiency figures

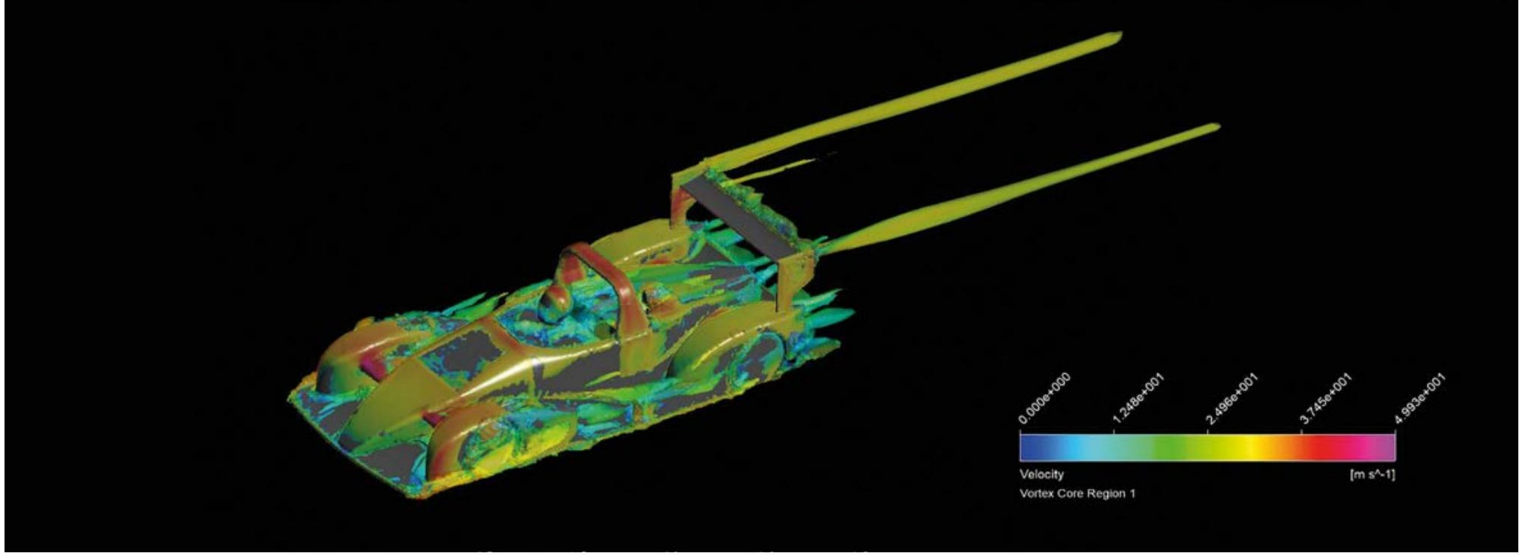


Over 40 iterations of bodywork design were tested before this design was decided upon as the optimal solution

'We actually had limited improvement from our 25th iteration onwards, but that was because we were trying to fine tune the balance rather than produce more downforce'

Tim Tudor, senior lecturer at Trinity St David





'It's effectively an entirely new set of clothes for the whole car,' notes Iley, although one aero part could not be altered. 'We still have to run the mandatory rear wing profile, which is part of Sports 2000, so we can't change that. But we have investigated one or two ways of maybe making it more effective or efficient.'

Interestingly, Tudor believes that aspects such as the strictly controlled rear wing, and working in a category with tight regulations in general, is good for the students.

'We pride ourselves here at the university in making sure students are doing industry-type projects, learning in the real world, and proving themselves in real competition.

'Sports 2 is a really level playing field with fairly tight regulations, and working within those is where the challenge is. We want to give our students that real world challenge.'

One of the strictest areas in those regulations is to do with the floor, yet this is also one of the most important avenues when it comes to Sports Prototype aero.

'We certainly have looked at the floor, although we are very limited in what we can do by the regulations, and so we haven't been able to do anything that isn't flat between the wheel centre lines,' confirms Tudor. 'But the real key challenge for the concept of a Sports 2 car in particular is that we're not allowed a diffuser. With not having the diffuser, how you manage that airflow, and that expansion, is key to producing a package. So we focused quite heavily on that, and we were impressed with what we could get, considering we were not allowed a diffuser to drive the underfloor.'

Naturally, the front splitter also received a great deal of attention. The new version is 'two inches longer and about an inch or so wider than on the old car,' says Hayes. He also notes that other knock-on changes to the S2N – as the new bodywork-clad car is called – over the original S2 version include the addition of another radiator, while the wiring harness has been relocated.

Once the aero development was complete, patterns were made by Iley Design – it turned into a perfect Covid lockdown project for Iley himself – and the moulds and finished bodywork crafted by Anthony Evans at MCR.

Final exam

The results of the project were that downforce was increased by a factor of two with no increase in drag, aero efficiency was doubled, and the CoP was moved forward, which improved the balance and helped address the understeer issue. All this was verified in the MIRA wind tunnel once the work was completed, thereby closing the loop.

'It's gone really well,' says Tudor enthusiastically. 'We've seen from our track testing, with pushrod load sensors, and our testing at MIRA, that the downforce prediction was reasonably accurate. We're generally very pleased.'

Final figures were verified by independent CFD, on track through pushrod load sensors and in controlled conditions at the MIRA tunnel

Of course, all this means nothing if the car does not perform on track. But suffice to say, at time of writing, an S2N has already won the Sports 2000 championship with a few rounds left to run, chalking up nine wins in 12 races. What's more, because the actual chassis has not been changed, existing MCR customers are able to upgrade their cars to the new version, with six having done so already, including the university-run car, which is driven by Tudor himself.

The only slight downside is the bodywork weight has increased a little bit, making it even more of a challenge to hit that 530kg minimum, but Hayes assures us the car is not far north of that figure now.

'We still have to run the mandatory rear wing profile, which is part of Sports 2000, so we can't change that. But we have investigated one or two ways of maybe making it more effective or efficient'

John Iley, professor of practice on the Trinity St David motorsport engineering course and head of Iley Design

Visual appeal

Overall, Hayes says he is very pleased with the results, and with the aero improvements that have been made he should be. But it's not just the aerodynamic modifications that have found favour with prospective customers.

'The aesthetics of the car attracts a lot of attention and, since we've had the new bodywork in place, we've had quite a few people inquiring about the cars because they actually like the look of them,' says Hayes.

Of course, most motorsport engineers will argue that how a car looks is wholly irrelevant, all that matters is how it performs, and that it's fast. But then most motorsport engineers also work in offices on anonymous trading estates in Motorsport Valley, rather than in a characterful race shop by the sea in an idyllic corner of Wales.

Photo: KJG Photography

The S2N has been an instant success, winning nine races out of 12 at time of writing and wrapping up the championship early in the season. The no.40 car pictured here is the Tim Tudor-driven Trinity St David car, upgraded with the new bodywork and aero package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Upright behaviour

How camber variation in steering influences suspension kinematics

BY CLAUDE ROUELLE

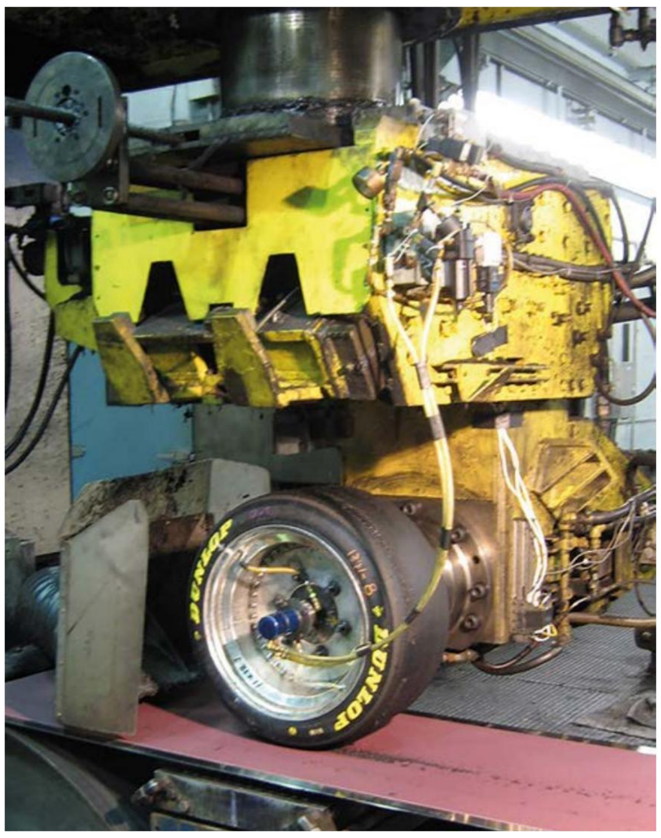
Continuing our study of perspectives on suspension kinematics, and how the design of the front upright influences many aspects of a car's performance, this month we look at camber variation in steering. This cannot be studied without first looking at camber variation in heave and roll.

Trying to ensure the right camber for each tyre at the right place at the right time is not that different to trying to achieve the ideal slip angle on each tyre, or the ideal front and rear ride heights at each position of each corner.

Wheel camber can be changed either statically on the set-up pad (most of the time with shims) or dynamically with the suspension kinematics. And different pick-up points will give you different camber variations in heave and roll.

For the front axles, different caster and KPI (king pin inclination) angles will give you different camber variation in steering. And while the camber angle is visible (an experienced engineer can see the difference between two and three degrees of camber), the slip angle isn't. That could therefore lead to a false assumption about the effectiveness of a camber change.

Wheel camber can be changed either statically on the set-up pad, or dynamically with the suspension kinematics



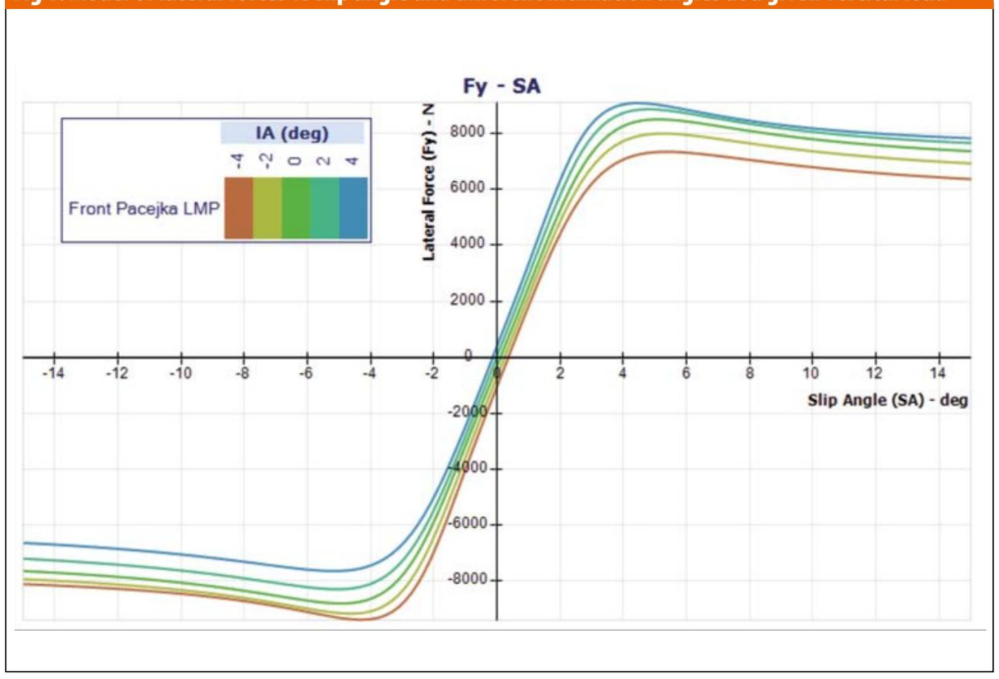
On a flat track tyre testing machine what is positive or negative camber? Which direction is the belt moving? Is it a right or left wheel? Hence the notion of inclination angle

Inclination angle

To illustrate this statement, let's look at **figures 1** and **2**. In **figure 1**, we can see the tyre lateral grip at a specific vertical load (not indicated here) for a sweep of slip angles from - 15 to + 15 degrees and five different inclination angles from -4 to + 4 degrees. Inclination angle? A few words about that. When you look at a car, we all know what positive and negative camber is because we use the car itself as a reference. But what is a positive or negative camber of a wheel when a bicycle or motorcycle leans to the inside of a left-hand corner? How can we define the sign of the camber angle when you only have one wheel, and the reference is the ground?

The same issue presents itself on a tyre testing flat track machine, as shown in the opening image. Inclination and camber can have the same or opposite sign depending which wheel, left or right, we look at. Going from the tyre to the

Fig 1: Model of lateral forces vs slip angle and different inclination angles at a given vertical load



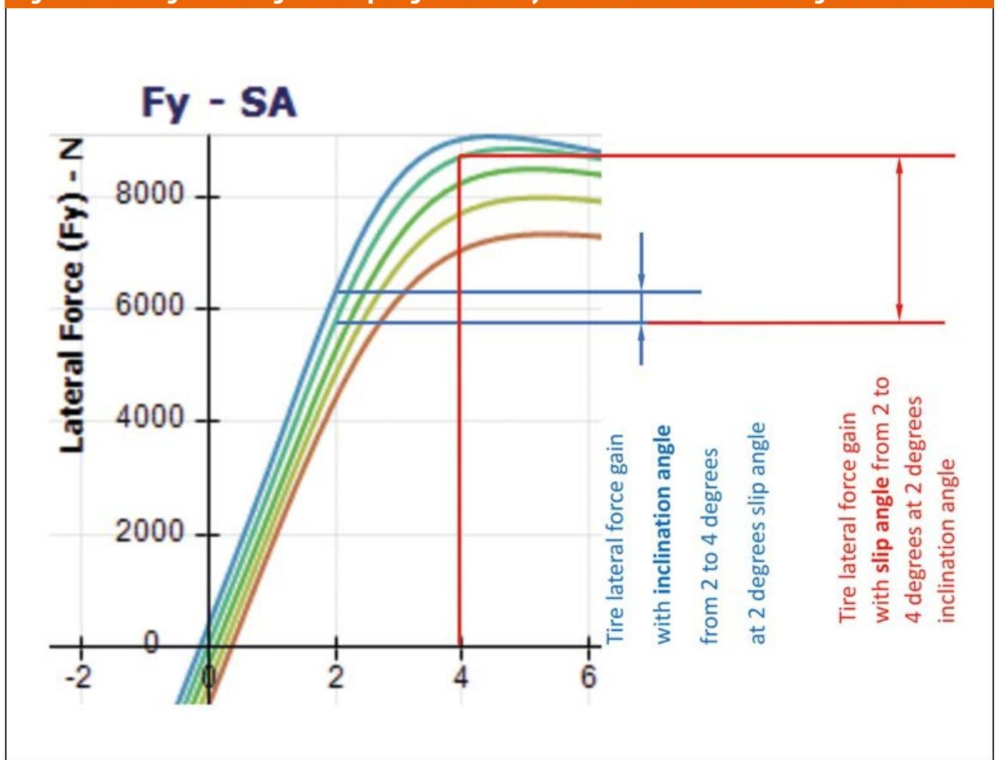
Slip angle and camber are both expressed in degrees, but one degree of one does not have the same effect as one degree of the other

car coordinates system is therefore a trap into which many new vehicle dynamics engineers invariably fall. So much so, the issue is worthy of an article in its own right, and maybe we'll come back to that in a future issue. For now, though, let's just say that in **figures 1** and **2**, a positive inclination angle is a negative camber for that wheel.

Slip angle and camber are both expressed in degrees. But one degree of one does not have the same effect as one degree of the other. **Figure 2** is a zoom of the previous figure, and shows that two degrees of camber change has much less influence on the tyre lateral grip than two degrees of slip angle. Sure, any grip you can gain will always be useful, but the graph demonstrates the importance of slip angle more than camber.

If the rules would allow, I would prefer to work on a four-wheel steering system, such as we have seen (briefly, as it was quickly banned) in Formula 1 in the past with the Michelin OPT on the Tyrrell, rather than a variable camber system.

Fig 2: Zoom of fig 1. One degree of slip angle will always do much more than one degree of camber



Optimal camber

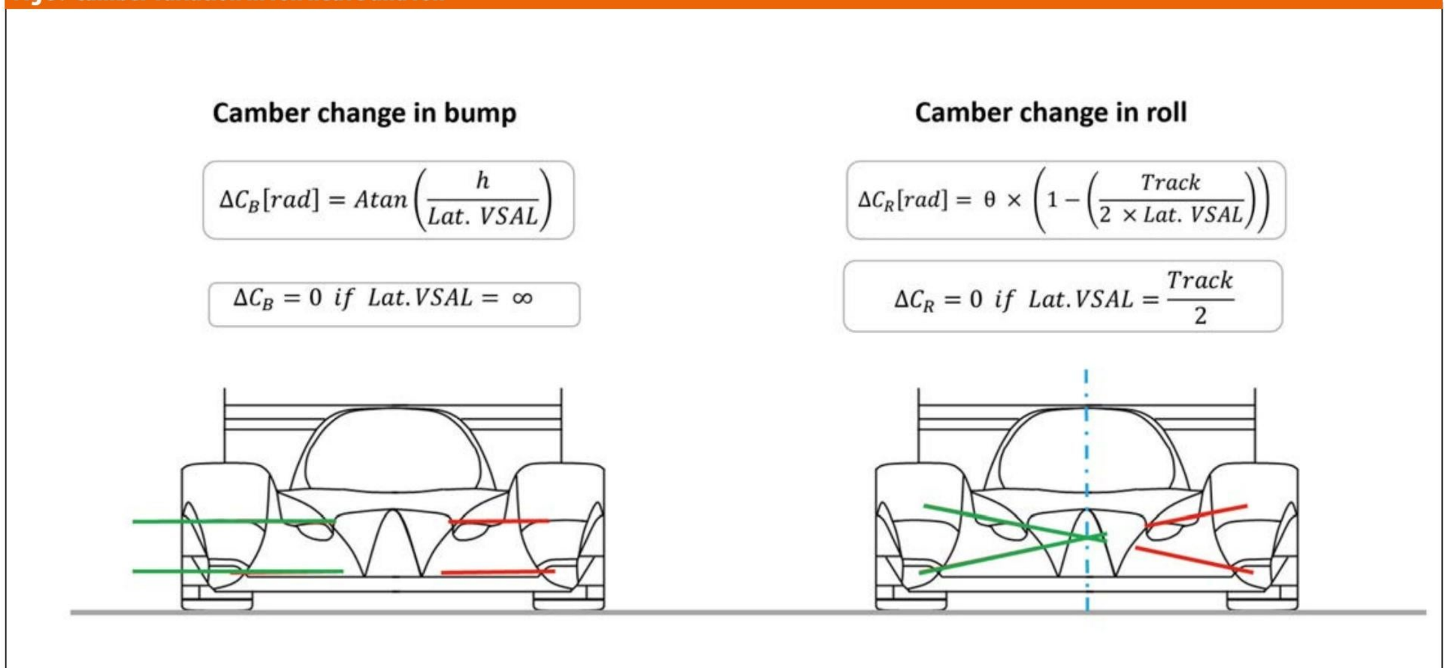
If the search for the optimal camber has little return on investment in grip, it has an enormous influence on tyre performance, consistency and reliability, all of which are critical factors. What we see in **figures 1** and **2** doesn't show how static camber, or camber variation, are detrimental to tyre wear (and especially uneven wear) on several laps of a circuit, or a long special stage.

As explained in a previous article, and as shown in **figure 3**, the camber variation in roll and heave are a function of the length of the virtual swing axle length (VSAL), which is the distance between the wheel and the instantaneous centre of the wheel vs the chassis.

A little advice here, if I may. **Figure 3** shows only static VSALs. Of course, the VSAL changes as the car rolls and moves up and down. Sometimes a good compromise between camber variation in roll and heave can be found by a shorter top wishbone and a longer low wishbone, but it's not always as straightforward as that.

As lap time is made much more in corners than in the braking and acceleration zones, control of the camber variation in roll is *always* more important than the camber variation.

Fig 3: Camber variation in roll heave and roll



In **figure 4**, we can see the effect that camber stiffness has on lateral grip. We can observe that camber stiffness is not linear and is quite dependent on slip angle, vertical load and initial camber.

Camber stiffness

By camber stiffness, we mean how many Newtons of lateral grip are gained for one additional degree of camber. Just as the cornering stiffness is expressed in Newtons of lateral grip per degree of slip angle, the camber stiffness is expressed in Newtons of lateral grip per degree of camber.

Figure 5 shows the effect camber has on longitudinal grip. If we compare the Y axis scaling of **figures 4** and **5**, we observe that the effect one additional degree of camber has on longitudinal grip for different slip ratios is minimal compared to the effect one additional degree of camber (**figure 4**) has on lateral grip for different slip angles.

In other words, a given VSAL will give camber variations in heave and roll but will influence the lateral grip much more than the longitudinal grip.

In **picture 2a**, we can visibly see the detrimental effect on tyre performance of a very long VSAL. That car was heavy, had a high c of g and needed relatively soft suspension to absorb chicane and corner kerbs. Therefore, the roll angle was much bigger than on a stiff car such as a Formula 1. But because of the long VSAL, and the amount of roll angle, to reach the ideal dynamic camber on the outside wheel, the team had to run massive static negative camber. Consequently, blisters appeared on the inside part of the tyres after just a few laps.

A much shorter VSAL helps in this situation. However, in some racing series, once the car is homologated, the suspension pick-up points cannot be moved. But at least a search for a better kinematics can be conducted during the development phase.

From what I have observed, it seems GTE cars in endurance series are designed with much smaller lateral VSAL (around 1.5-3m) than LMP cars (generally from 5-7m, sometimes even more). Taking a few pictures, especially with no bodywork on, will show you that. Yes, I agree the cars have different weights, c of g heights, suspension stiffness, ride height changes, tyres and aeromaps, but I still sometimes wonder how many racecar manufacturers can design a suspension kinematics around given tyres.

The long and short of it

Tyre engineers keep telling race engineers they run too little pressure (or do have not a good tyre pressure management) and too much static camber. Often, if the car designer had imposed a shorter lateral VSAL, the car would not need that much negative camber so tyre performances will be more consistent and the the tyres more reliable.

Yes, front and rear tyres require different suspension kinematics, but still I have observed on cars that win races and championships that most of them have a longer VSAL on the rear than on the front.

Why? Because on the front we also have camber variation due to the steering.

Fig 4: Camber stiffness effect on lateral grip for a given pressure

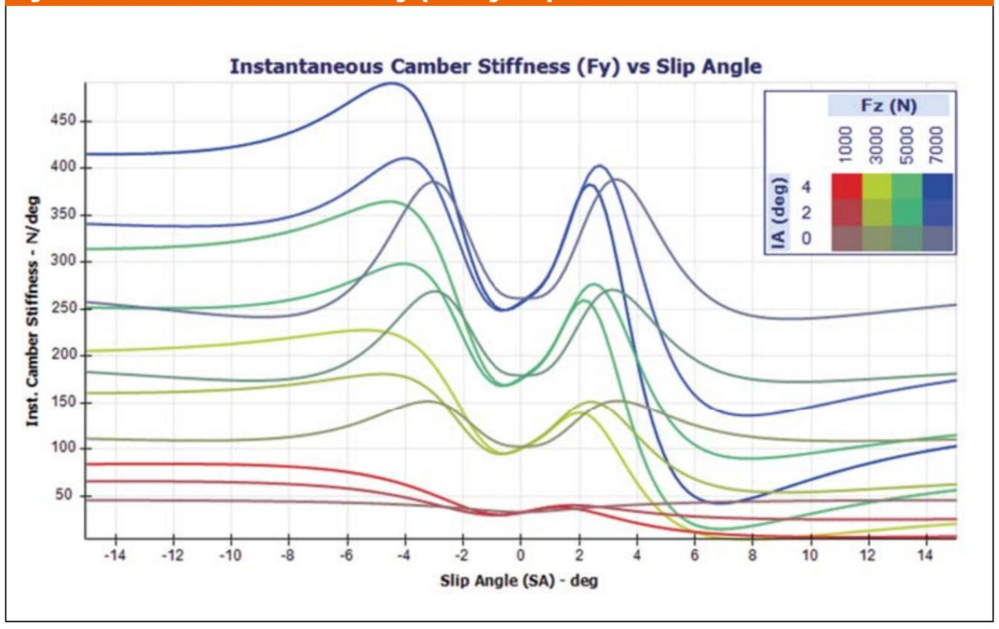
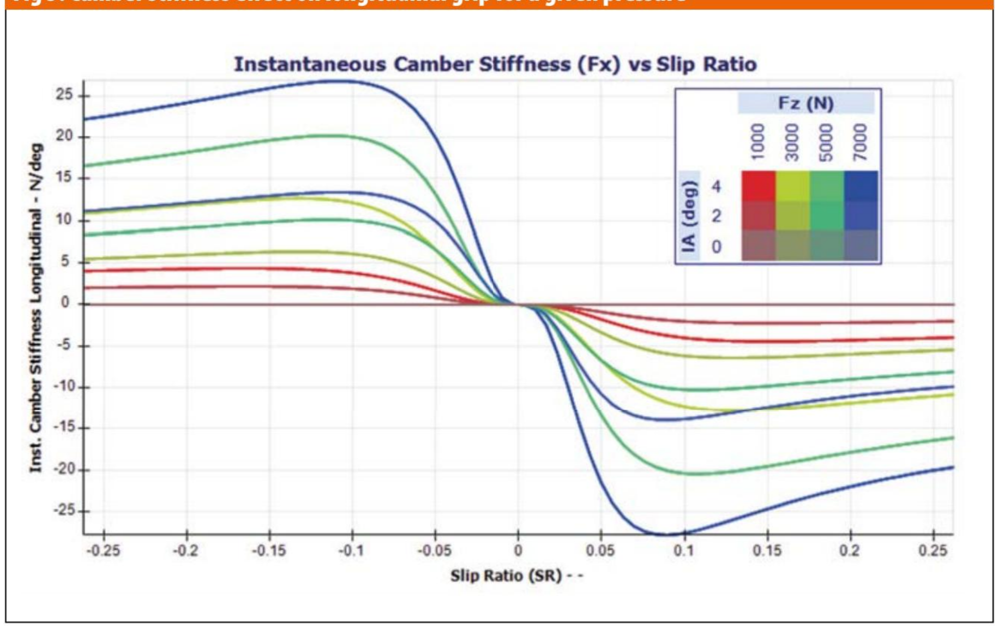


Fig 5: Camber stiffness effect on longitudinal grip for a given pressure



Pic 2a: Example of a racecar development OptimumG was involved in. Initially, we had very uneven front tyre wear and major loss of performance in just a few laps because of a very long VSAL. Only a small part of the tyre is working, and a major part has serious graining

Pic 2b: Improved tyre wear and car performance after OptimumG suggested, within several other parameters, a much shorter lateral VSAL. We can see the result on right front tyre wear, with much less graining, though there is still room for further improvement to be made

In **figure 6**, we can see the steering-induced camber variation of a car at rest on a set-up pad. In a left-hand corner (positive steering angle), the RF camber increases by 1.5 degrees from -2.5 to -4.0, while the LF decreases 1.7 degrees from 2.7 (asymmetric static camber on that car) to 1.0. Usually, in absolute value, the camber variation is bigger on the inside wheel than the outside wheel.

We also observe the slight variation of rear wheel camber created by the steering-induced corner load variation.

Picture 3 shows camber variation in steering on a Formula Student car. Most probably the outside wheel does not have the ideal camber. We must therefore wonder how much of this camber variation comes from poor suspension design or compliance. Students learn more from mistakes more than success, but a knowledge of the tyre characteristics and basic suspension design best practices could easily have avoided this issue in the first place.

The simplified equation of the camber variation in steering is as follows:

Steering-induced camber variation = KPI angle x (1 – cos (steering angle)) – caster angle x Sin (steering angle)

The cosine of the steering angle is associated with the KPI angle. The sine of the steering angle is associated with the caster angle. As the cosine of the steering angle is the same whatever the sine of the steering angle, but the sine of the steering angle is steering angle sine dependent. We can therefore understand why the steering-induced camber variation is more dependent on the caster angle than the KPI angle, as shown in **figure 7**.

In conclusion, a compromise between camber variation in roll, heave and steering helps get the most out of a tyre, something that is worth understanding before designing, or exploiting, a car with a suitable set-up.

In the next article, we will discuss the importance caster and KPI angles and trails have on the ride height variations.

Fig 6: Camber variations from -90 to +90 degrees of steering

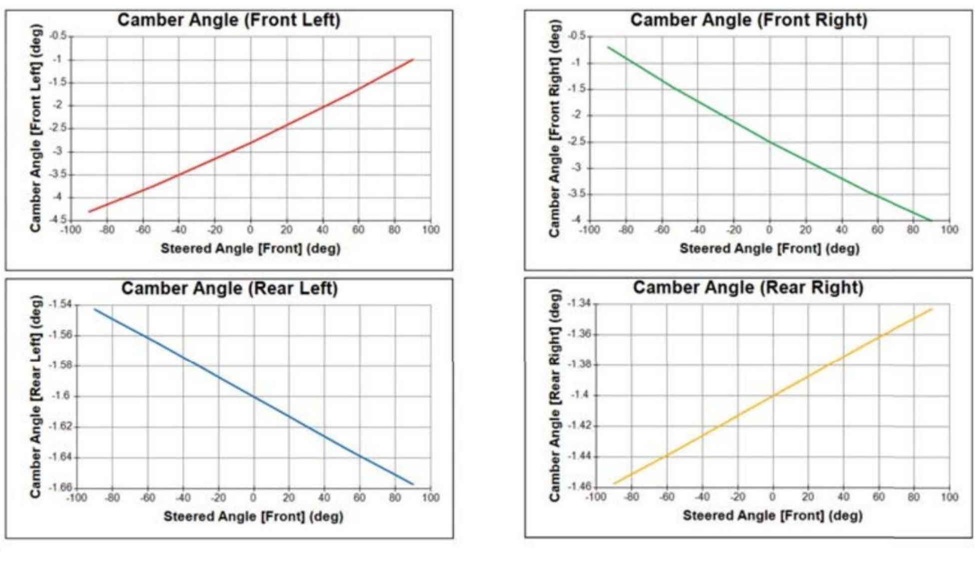
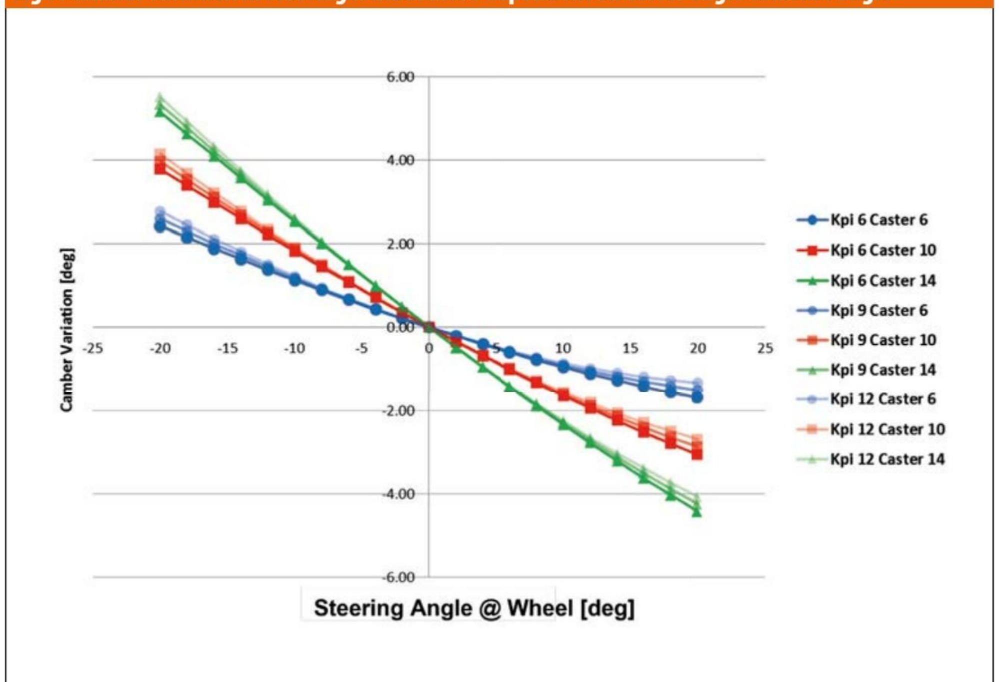


Fig 7: Camber variation in steering is much more dependent on caster angle than KPI angle



Pic 3: A poor example of camber variation in steering, with the effect on tyre wear clearly visible

Slip Angle is a summary of Claude Rouelle's OptimumG seminars.

Public, on site, and online OptimumG seminars are held worldwide throughout the year. The Advanced Vehicle Dynamics and the Data Driven Performance Engineering seminars present several theories and best practices that can be used by engineers when making decisions on how to improve vehicle performance. OptimumG engineers can also be found around the world working as consultants for top level teams.

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Inner vision

Do you know your CT from your CMM?* Racecar *investigates the latest developments in metrology

By STEWART MITCHELL

The use of metrology in motorsport has increased significantly over recent years, thanks to improvements in systems, coupled with the ever more challenging reliability and durability targets being imposed across many forms of racing

Metrology is the science of measurement. Motorsport uses it at each stage of a racecar's manufacture and development to ensure part tolerances, surface finishes, geometries and internal structures are all to the desired specification.

This use of metrology has increased significantly over recent years, and the range and number of metrology devices used in motorsport today are vast. Without them, racecars may not make the cut when it comes to performance and, in some cases, could suffer complete failure.

The spike in uptake of this technology is thanks to improvements in the metrology systems themselves, coupled with the increasingly challenging reliability and durability targets being imposed across many forms of racing.

To truly validate the geometry and construction of the components that make up racecar sub-assemblies, engineers must go beyond the basic measuring tools, such as Vernier calipers, rulers and tapes. Way beyond. Although the range of metrology systems used by modern racecar manufacturers are vast, here we cover the science behind coordinate measurement machines (CMM) and computed tomography (CT) scanners.

Axes of inspection

A CMM exploits three orthogonal axes – x, y and z – operating in a 3D coordinate system and provides precise dimensional inspection of manufactured parts. As such, they are integral to many measurement and quality control processes in a wide range of industries.

XPB

A CMM exploits three orthogonal axes – x, y and z – operating in a 3D coordinate system and provides precise dimensional inspection of manufactured parts

Each axis has a scale that indicates the position of the measurement tool, which is usually a touch probe with a ruby or steel tip, and an optical sensor or laser.

In motorsport component development, CMMs are regularly used during post-production inspection. The measurement process can occur within the CNC machine, as part of the CNC program, or by a dedicated CMM.

The probe's movement is directed either by the operator or a computer program, and uses the logged coordinates to determine the precise geometry, or features, of the component under examination. A computer connected to the CMM then logs the input from the probe.

Most precision racecar parts are examined using this technology, including the chassis, engine block, suspension components, transmission assemblies and more. Any fixtures that support components machined on multi-axis CNC machines are also regularly measured to look for any wear or discrepancies. This ensures any machining processes remain accurate, and the correlation between the computer aided manufacturing (CAM) program and the finished part are within the desired tolerance. Engineers will often check sub-assembly components multiple times before they reach a car and it rolls out.

Control programs

In recent years, one of the largest development areas for CMMs has been control software programs. These have improved CMM accuracy, reliability and speed. There are now CMM programs that optimise the travel path of the probe around a work piece in the most time-efficient way after the user has defined the features they want the CMM to measure.

Some CMM software packages can even recognise features from the CAM files and know when to skip over a hole for a bolt in a surface being measured, for example, yet still identify pores or damage on that same surface.

The very latest surface roughness sensor programs allow CMMs to simultaneously measure dimensions and surface roughness during a single CMM operation. That saves the user from setting up two separate operations, further improving efficiency.

CMMs come in a range of performance levels to accommodate different types of measurement, levels of accuracy, speed and cost. CMM users must therefore select the correct equipment for the task they have in mind. As a rule of thumb, most manufacturers suggest selecting a CMM between four and 10 times more precise than the most challenging part tolerance they need to measure for the highest level of accuracy.

Zeiss

CMM laser scanners provide an efficiency boost to traditional CMM by offering high accuracy, non-contact feature and surface measurements with no part preparation

Faro

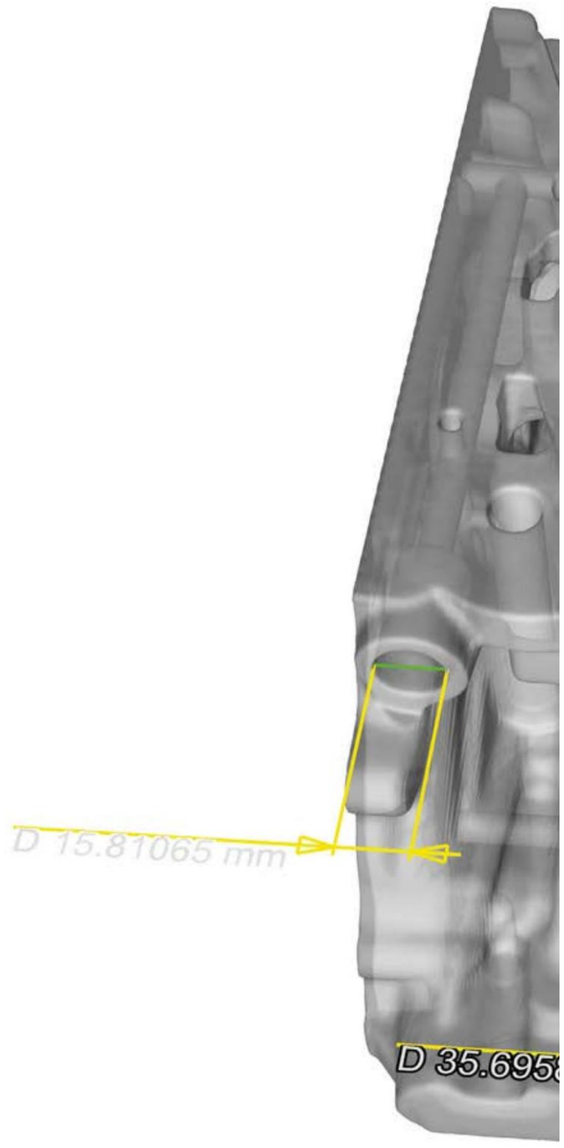
In recent years, one of the largest development areas for CMMs has been control software programs

An example of a metrology array, used to measure the surfaces of a vehicle to correlate CAD files to final product dimensions

Nikon

The latest CMMs capture the smallest details with the highest levels of accuracy, providing valuable insights for components ranging from small aerodynamic devices to intricate fabricated sheet metal parts

Image of CT scan showing the internal structure of a cylinder head



Naturally, that is reflected in the cost, so users must select the appropriate machine for their application, and budget.

Probe heads

Other factors to consider include the type of geometric features being measured, the manufacturing process used to create those features, and the design or development phase of the component / assembly. The elements that are influenced by these factors include the machine's structure – whether it be a moving bridge, fixed bridge, gantry, cantilever or another type of CMM – as that can impact their precision. The fundamental difference between each type is the amount of movement the measurement probe has.

A fixed probe head machine, such as a fixed bridge, has a moving bed and the component being measured is held on the bed and brought to the probe. The bed is usually a granite block supported on air bearings to keep it as flat and perpendicular to the probe tip as physically possible. An indexing probe head, on the other hand, such as that found on a gantry-type CMM, has a moving probe. Here, the measured part stays fixed, and the probe head is brought to it.

The general consensus among CMM manufacturers is that a fixed probe head tends to be more precise. However, modern indexing and multi-axis probe combinations often provide acceptable precision and add flexibility in that the geometries they measure can be more complex.

Like fixed CMMs, multi-axis probe heads use a touch probe but, instead of being able to move only within a fixed envelope, the probe is attached to the end of an articulated arm. There are usually six joints on this arm, and each has an embedded encoder disc that logs its exact rotation. From information gathered by the encoder, the machine can calculate the probe's location each time a measurement is taken.

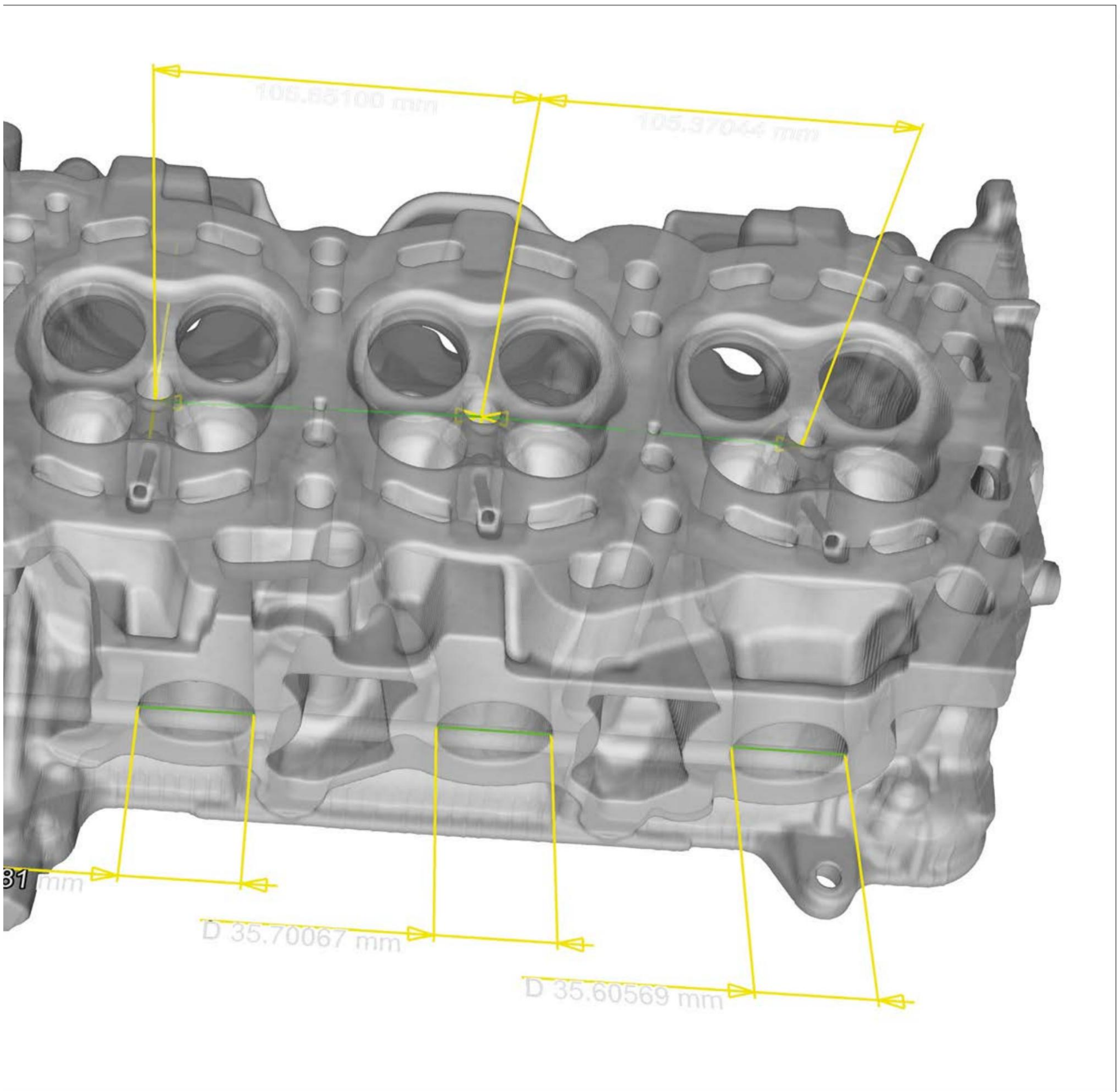
Ideally, the CMM would be housed in a temperature and humidity-controlled atmosphere, although in the world of motorsport that is not always practical.

Overall, CMM measurement is critical to manufacturing productivity and, in the case of CMM performance, one size does not fit all. Therefore, assessing the performance requirement of any CMM is a case of finding the right level of technology to suit the specific requirements of your application.

CT scanning

X-ray computed tomography (CT) scanning is a technique whereby a component or system is exposed to electromagnetic radiation and, through this, the internal structure of it can be seen. A computer processes pictures of this electromagnetic

When the x-rays pass through a part, they generate a representation of the structure of that part based on how strong the x-ray signal is on the other side



NorthStar Imaging

exposure from different angles to produce cross-sectional (tomographic) images of the object in question.

In CT scanners, x-rays are generated by components called x-ray tubes, which produce a heavy stream of electrons. They then fire them at a reflector plate and the resultant energy from the impact of the electrons onto the reflector plate generates x-rays. The faster the electrons impact the reflector plate, the higher the x-ray energy.

The downside is that X-ray tubes are not very efficient. On average, more than 90 per cent of the energy produced by the beam is turned into heat.

The x-rays penetrate the component, and the amount absorbed by the component is a function of its density. When the x-rays pass through a part, they generate a representation of the structure of that part based on how strong the x-ray signal is on the other side. Turning that signal into data that a computer can use to produce a digital image of the structure of the scanned component is the detector's job.

The smallest allowable pore or defect in the part, and its location, define the minimum allowable 3D pixel size. CT scanning creates a 2D representation of the component that, when combined with image stitching and 3D modelling software, produces 3D internal and external renderings.

Non-destructive testing

The technology allows for the investigation and analysis of the internal structure of a component without having to physically cut it open (known as destructive testing and analysis). It has been used for several years for flaw detection, failure analysis, assembly analysis and reverse engineering of components in industrial applications. However, as a metrology technology, it is still relatively new compared to other techniques such as CMM.

For racecar development companies, CT scanning is useful at many stages of the development process, particularly regarding design tolerance and manufacturing process validation.

For example, racecar components that are forged, or cast, will frequently be subject to intensive post-process machining before they go into service. As the casting process will often be far cheaper than the machining one, it is vital that the machinist is confident of the integrity of the part before any such operation is carried out.

Modelling software

Turning the 2D detector data into an image that can be modelled in 3D for analysis is the job of the modelling software. It is here that some of the biggest improvements in CT scanning technology have been in recent years. Combined with the latest computing power that has reached this market in the past few years, the software has helped speed up production of 3D models.

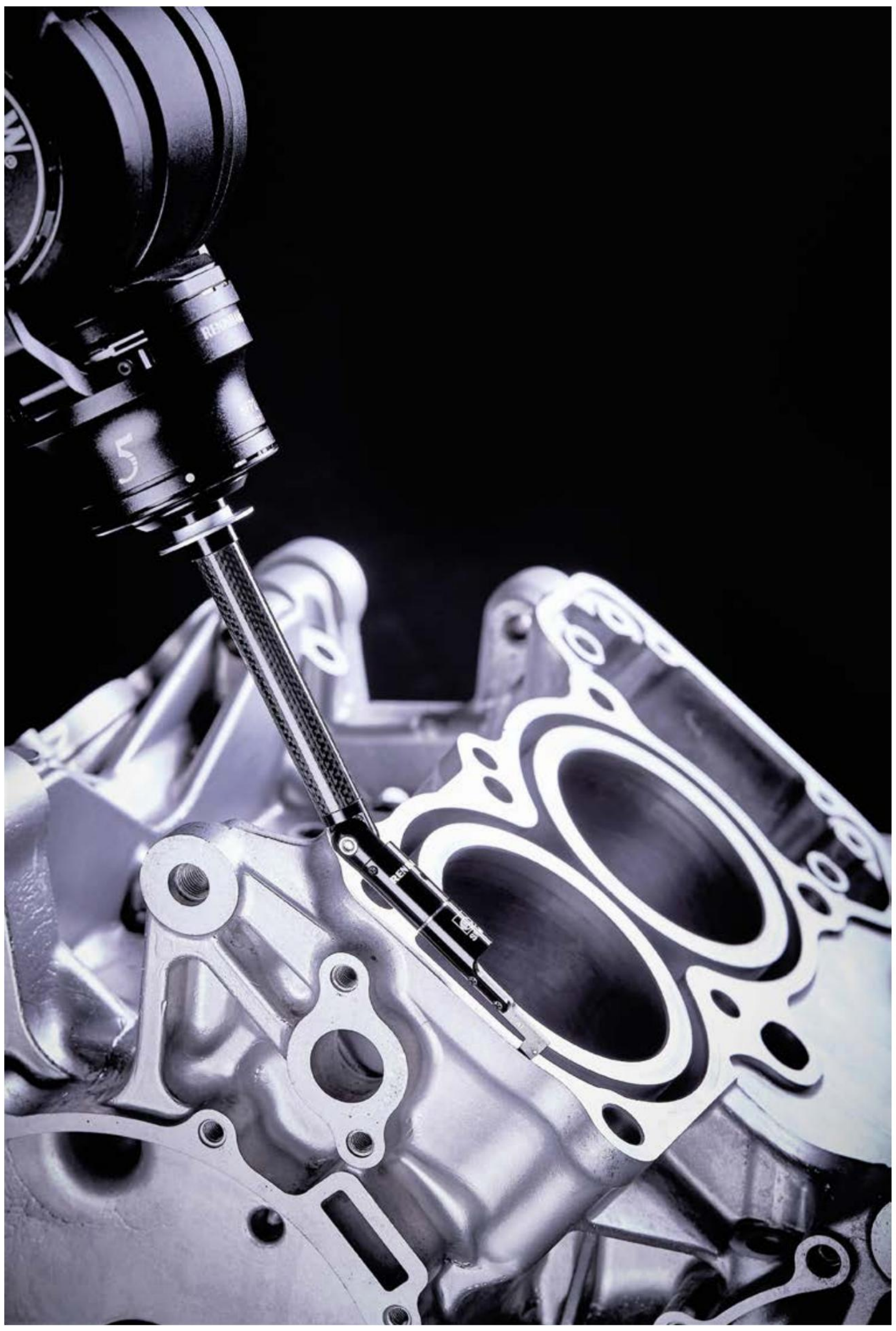
Some software can even accurately dimension the component under investigation when the model is displayed on a screen, automatically analysing and comparing it to the original engineering drawings / CAD files.

The latest software can not only create a full 3D model of the component structure with all the dimensions in place, but the model can be cut and manipulated, and the user can investigate the internal geometries through every millimetre of the part as well. In that regard, it is as sophisticated as the latest CAD packages.

These high-end CT software packages can also compare CT scan and CAD models. Here, software can overlay the 3D model onto the original CAD model, and the software can give the user an indication of where the CAD model differs by showing a colour map or similar projection.

Some advanced 3D CT scanning analysis software packages have features allowing the user to carry out porosity analysis. Such systems can display porosity by volume, show how much of a part is made up of pores, where the pores are, how big they are and whether the part is acceptable for use under predefined limits of acceptability. To achieve this, each part must be accurately loaded into the CT scanner using robotic arms, tool holders and / or fixtures in the scanning bed. This technology is particularly useful for medium to high production runs of the same part, as the predefined analysis program can pass or fail a part quickly and relatively accurately.

Whether or not a component can be CT scanned at the desired level of detail comes down to the component size and material. The denser the material, the more difficult it is to penetrate it with x-rays, and therefore the lower the resulting resolution of the scan data.



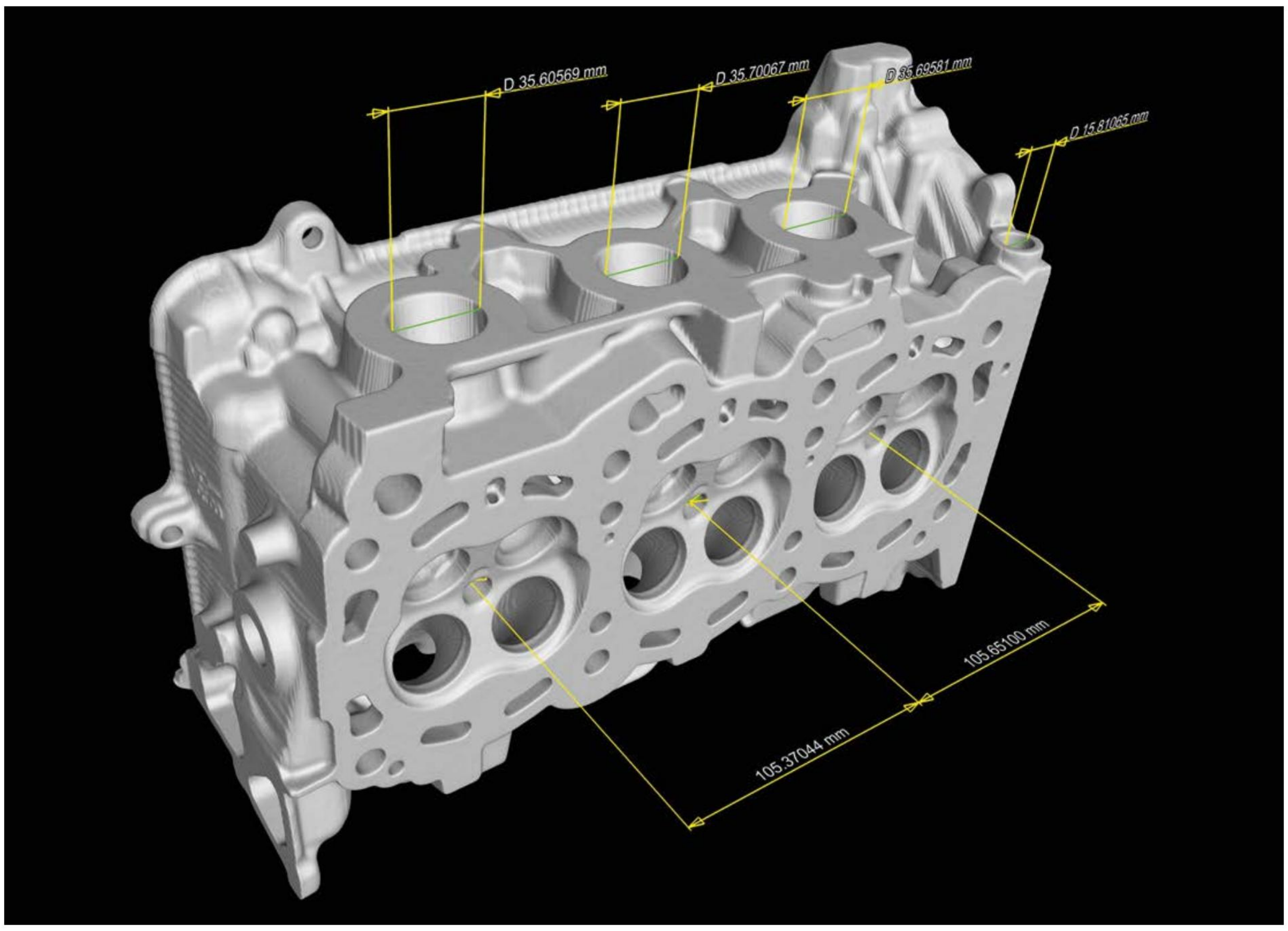
Renishaw

A touch probe measuring the geometry of a part and its surface finish

The size of the part is another consideration, as the largest object that will fit into the current biggest industrial CT scanning machine is 1500 x 1500mm.

The x-ray tube's power and the detector's resolution can be specified when the CT scanner is built. The customer can also specify the 3D data resolution if the part is sent to a scanning bureau, provided they have the machinery to complete the job to the desired specification.

[CT scanning] is becoming increasingly popular for analysing complex parts made using additive manufacturing (AM) techniques



NorthStar Imaging

CT scan image of cylinder head surface model with measurements of port and centre-to-centre dimensions that can be correlated with CAD data

The industries driving industrial CT scanning technology are predominantly military and aerospace. Automotive and motorsport only really use this technology for high value (in terms of cost and / or performance) or safety-critical parts. In most cases, such components tend to be low-volume productions, so destructive testing is not economically viable.

CT scanning can measure features inside a part that would be impossible to reach with other metrology techniques, such as CMM or laser scanning. Consequently, it is becoming increasingly popular for analysing complex parts made using additive manufacturing (AM) techniques.

AM is still a relatively new technology, so there is high demand for tools that can perform detailed analysis of parts made this way. Crucially, CT scanning can identify porosity between construction layers, which would be impossible to see with more basic analysis techniques. Automated pass or fail CT scanning technology has not yet been brought in to analyse AM components, but it's surely only a matter of time.

In the future, we expect to see metrology systems networked with the manufacturing floor through industry-standard communication protocols that can remotely diagnose measured parts. They will also operate more accurately in adverse workshop conditions and offer a broader range of tactile and non-contact sensors fitted to common CMM frames, running common software.

CT scanning's future will include larger machines that can scan bigger parts. The x-ray industry already has tubes that can produce much more power so x-rays can penetrate through larger, or denser, materials, but the detector technology needs to catch up.

Setting the standard

The ISO standards group, and other engineering commissioning standards agencies, are working together to define a standard for metrology using CT scanning. Once those standards are finalised, and defined operations for CT scanning grades of certain value / quality parts are laid out in a clear-cut process, CT scanning will be able to define accuracy statements just as other metrology systems do now.

Developments in the field of metrology particularly relevant to anyone manufacturing racecar components have been the increased speed of data collection from the part and improved resolution and accuracy.

Automated metrology technology offers a huge leap in quality control assurance, repeatability and durability

Access to equipment has also improved significantly over the past few years. And as the operational procedures become more automated, so high-end metrology systems become a more available option for a broader customer base. Even just five years ago, the machines discussed in this article required a highly trained operator to use them, an overhead that smaller development companies may not have been able to justify.

When it comes to motorsport, every component of a racecar is meticulously measured for accuracy to ensure it both fits and is fit for purpose. Automated metrology technology offers a huge leap in quality control assurance, repeatability and durability, offering efficiency levels never before seen in the motorsport engineering sector.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2030: a fuel odyssey

F1 is ramping up its search for the fuel of the future. In the first of a two-part analysis, we look at what we might expect to see happening in the next 90 months

By PETER WRIGHT

The climate is changing. It is difficult to be unaware of the heat waves, wildfires, glacier and Arctic / Antarctic thawing and flooding emergencies currently affecting many nations as a consequence. Scientists agree that, even if the effect is a natural climate cycle, increased CO_2 in the atmosphere is exacerbating the effect, and that only humans can do something about it.

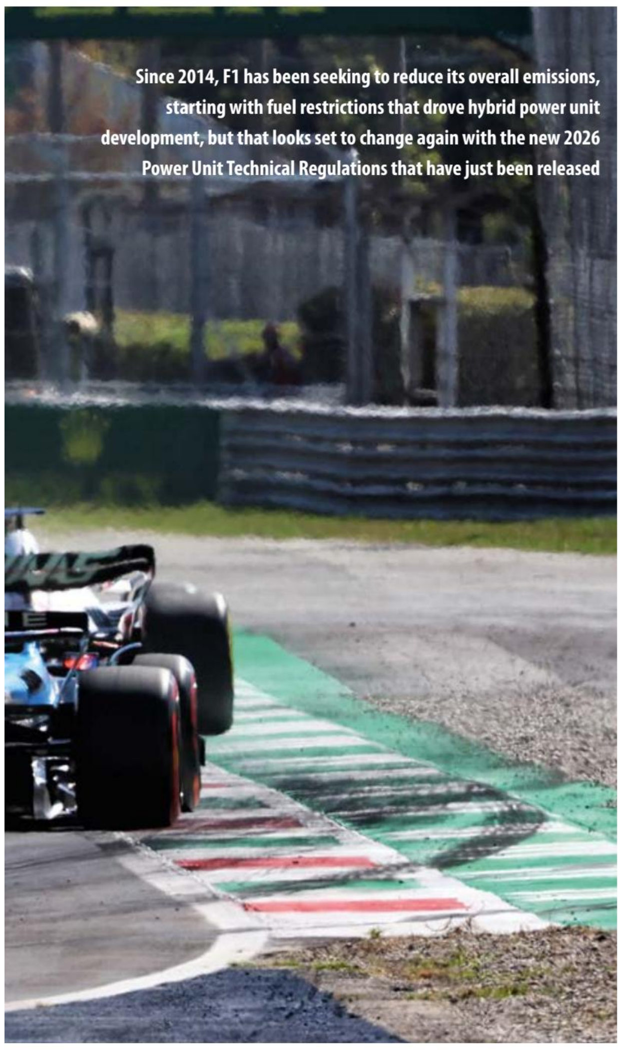
More than 70 nations have pledged to achieve net zero CO_2 emissions and so hopefully limit global temperature rise to under 1.5degC in 2050. To be successful requires immediate action to halve global emissions by 2030, and that is just 90 months away from now.

Most people accept that F1's emissions from the tailpipes of its cars is negligable in the great scheme of things, though the contributions of travelling fans is not. This issue is not confined to F1 among international sports, incidentally, but the difference is F1 has an increasing influence on the car buying and driving habits of consumers worldwide, there being around 1.5 billion cars serving the eight billion people currently living in the world.

Efficiency drive

In 2014, F1 set out to become more efficient with a set of power unit regulations that reduced the amount of fuel required to complete a race by one third. This has resulted

Hybrids are the type of power unit the automobile industry would like to sell, retaining their traditional ICEs while, at the same time, being able to claim sustainability credentials



Since 2014, F1 has been seeking to reduce its overall emissions, starting with fuel restrictions that drove hybrid power unit development, but that looks set to change again with the new 2026 Power Unit Technical Regulations that have just been released

in hybrid powertrains that achieve over 50 per cent efficiency, compared with 30+ per cent of the high-revving V8s and V10s of the preceding generations.

In 2018, Liberty Media allowed Netflix to film *Drive to Survive*, and to repeat the process every year since. This excellent and entertaining documentary series has exposed F1 to a wider audience, especially in the USA. The resulting surge in popularity has caught the attention of, among others, the legacy motor industry and its essential partner, the energy industry.

These two industries, with their ICE factories, traditional dealer networks and fossil fuel reserves are under threat from EVs and renewable energy, and are staring the stranding of their assets in the face.

F1 cars are currently each limited to 110kg of petrol per race, an energy equivalent of about 1400kWh. Only a liquid hydrocarbon is able to achieve an acceptable energy density for storing this quantity of energy in a car, and so F1 is inevitably limited to a hydrocarbon-burning ICE core power unit, topped up with as much energy as possible that can be recovered from the retarding of the car and from the exhaust ie a hybrid, compound-ICE power unit.

Hybrids are the type of power unit the automobile industry would like to sell, retaining their traditional ICEs while, at the same time, being able to claim sustainability credentials.

F1 has an increasing influence on the car buying and driving habits of consumers worldwide

Marketing partners

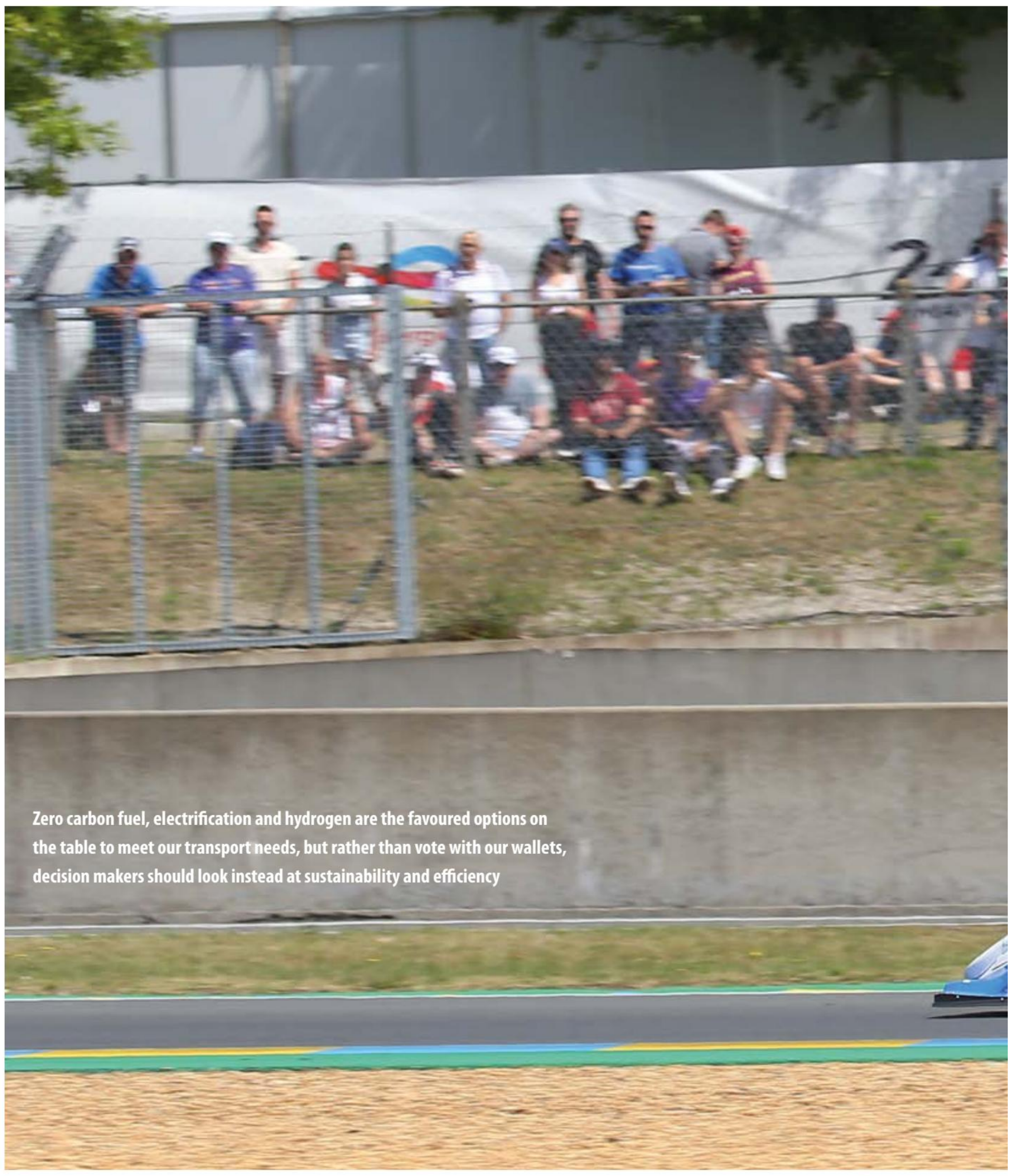
With the energy industry knowing it has to transition to zero net carbon, and hence find ways of making and supplying sustainable fuels, these two partners approached F1 (FIA and FOM) to encourage them to formulate new F1 power unit regulations along these lines. And then suggested they could become more involved in F1 as marketing partners. Just what FOM wanted, and the teams could see the value of their assets increasing.

In August this year, the FIA issued the 2026 F1 Power Unit Technical Regulations and this, in theory, allowed the auto manufacturers standing in the wings to step forward. These regulations are highly complex, but two fundamental changes stand out:

Firstly, the MGU-H is deleted. The consequence of this is that the overall efficiency of the power unit will decrease from something over 50 per cent to probably something under 40 per cent. Time will tell. The argument for this is that the MGU-H is

Though the racecar emissions might grab the headlines, it's the additional travel burden, not least the legions of fans travelling to watch races, that ramps up the global effect of motorsport

The FIA has decided to encourage the energy industry to be heavily involved by making fuel supply competitive


Zero carbon fuel, electrification and hydrogen are the favoured options on the table to meet our transport needs, but rather than vote with our wallets, decision makers should look instead at sustainability and efficiency

too high revving and too high temperature to use on a production ICE. Or, more likely, too hard for newcomers to catch up with the incumbents on development.

Secondly, the fuel used would be 'Advanced Sustainable' (AS). What are AS fuels? See Article 16.1, basic principles:

'With regard to fuel, the detailed requirements of this Article are intended to ensure the use of Advanced Sustainable (AS) fuels comprising solely AS components, that are composed of certified compounds and refinery streams and fuel additives and to prohibit the use of specific power-boosting chemical compounds. The final, blended fuel must achieve a greenhouse gas (GHG) emissions savings, relative to fossil-derived gasoline, of at least that defined for the transport sector in the EU Renewable Energy Directive RED(1), which was current on January 1st in the year prior to the relevant Formula One Championship.

'The GHG savings calculation takes into account any net carbon emissions from land-use change, the energy used in harvesting and transporting the biomass and the production and processing of the advanced sustainable component. In any process where sustainable energy is used, this must be surplus to the local domestic requirements. Where available, GHG emission savings will be taken from the current EU Renewable Energy Directive (RED) or other equivalent, internationally recognised sources.

'The use of these compounds and refinery streams in F1 fuel will be dependent on evidence indicating that the supplier is genuinely developing these compounds for use in commercial fuels and that they are available from plants capable of producing at least 5m3 per year or are commercially available at similar volumes from a third party. Acceptable compounds and compound classes are defined in 16.2 and 16.4.3.

'In addition, to cover the presence of low-level impurities, the sum of components lying outside the 16.2 and 16.4.3 definitions are limited to 1% max m/m of the total fuel.'

Article 29, section 10(c) of Directive (EU) 2018 / 2001 for biofuels, and Article 25, section 2 for RFNBO

In other words, they are defined in the same terms that global institutions have used to define the essential components of sustainability – net zero and zero carbon.

Advanced Sustainables

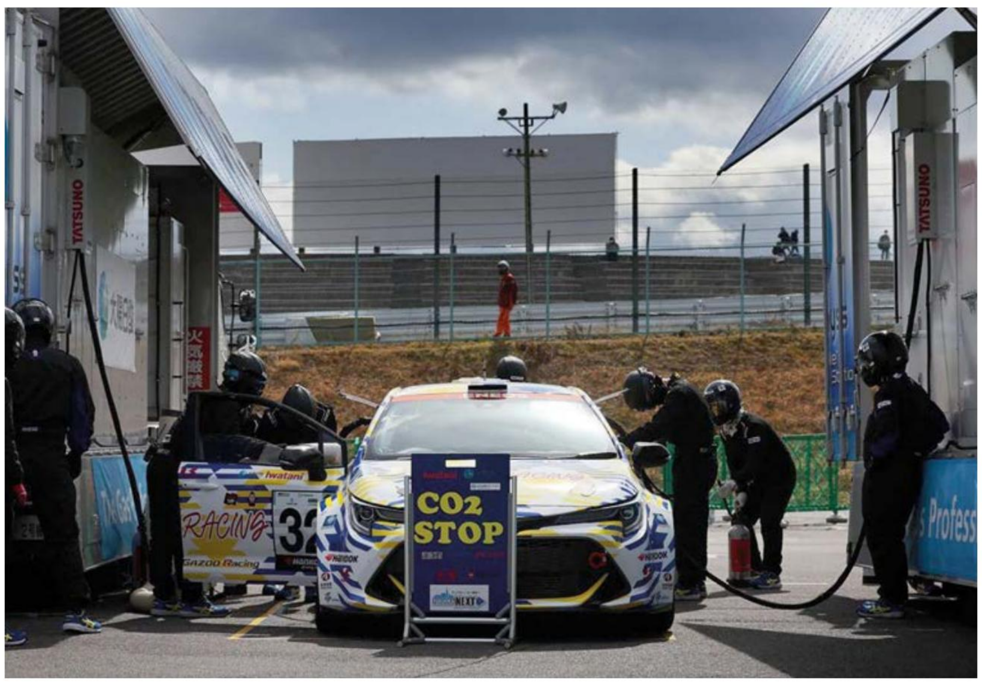
Whether you accept the need for any of these concepts being applied to CO_2 emissions depends on your views on the scientific process of peer review and consensus, as applied to climate change.

However, under Article 16.2 Fuel Definitions, we find 16.2.8 Advanced Sustainable component:

'An Advanced Sustainable (AS) Component is one that is certified to have been derived from a carbon capture scheme, a renewable fuel of non-biological origin (RFNBO), municipal waste, or non-food biomass. Such biomass includes, but is not limited to, lignocellulosic biomass (including sustainable forest biomass), algae, agricultural residues or waste, and dedicated non-food energy crops grown on marginal land unsuitable for food production. RFNBOs are considered renewable when the hydrogen component is produced in an electrolyser that uses new renewable electricity generation capacity.

'Biocomponents from food crops can be regarded as an advanced sustainable component only if they have already fulfilled their food purpose (e.g. waste vegetable oil because it has already been used and is no longer fit for human consumption). Furthermore, the biomass, from which the advanced sustainable component was made, must not originate from land with high biodiversity such as undisturbed primary forest or woodland, land designated for nature protection or highly biodiverse grassland, and were in this state in or after January 2008.

'Additionally, the biomass must not originate from any land with high-carbon stock such as wetlands and peatlands.'



It is all well and good saying Advanced Sustainable fuels have to be used, but the next problem is policing their production and use

This fuel component regulation is a mixture of permitted and banned sources, defined mainly in agricultural terms. These definitions apply to only 10 per cent of the current fuels, but in 2026 they will apply to the entirety of F1's fuels.

So, the next question is how will they be policed on the ground? Article 16.5.1.c Fuel approval states:

'Certification must be presented to the FIA, from a recognised body, assuring the origin and the calculated GHG reduction of each AS compound and AS refinery stream blended into any Formula One fuel blend submitted to the FIA for approval.'

The FIA has therefore decided to encourage the energy industry to be heavily involved by making fuel supply competitive. While it will be interesting to see FIA inspectors in wellington boots checking fuel component sources, would it not have been better if a single source AS fuel had been mandated, leading to the likes of ARAMCO and others bidding for the right to supply?

Drop-in solution

The physical properties of AS components are laid out in detail in the regulations and are very similar to conventional fossil fuel components used by F1. The idea being the new fuels will be a 'drop-in' solution.

But what exactly are Advanced Sustainable fuels, and what are their relevance to wheeled transport? Generally included in this category of fuels are e-fuels, synthetic fuels, e-methanol and hydrogen.

Why does society, or indeed F1, need them? To evaluate the various options, we have to look at the fundamentals, and to do that, we must go back to first principles. Please bear with me.

There are only two sources of energy available to us here on earth. Firstly, thermo-nuclear: the stars eg our sun; residual thermal energy ie geo-thermal; our attempts at nuclear fission and, one day, fusion. Secondly, orbital energy: energy extracted from tidal motion, powered by our moon orbiting the earth.

Avoiding the difficult and highly contentious subject of nuclear fission and fusion to generate electricity, our sun is the main and abundant source of energy exploited by humans. It takes a number of forms: solar thermal; solar voltaic; weather induced – wind, hydro; photosynthesis.

The latter generates hydrocarbons from the CO_2 in the atmosphere and water, and provides biomass for consumption by animals such as humans, and combustion. Historically, the biomass generated millions of years before we humans appeared has been stored as coal, oil and gas.

Only three atoms are essentially involved in the photosynthesis process: carbon, hydrogen, and oxygen. CO_2 and H_2O are combined with the energy of the photons from the sun that are absorbed by the green plant matter, and a variety of hydrocarbons are produced along with oxygen.

The natural world

The animal world uses the oxygen to burn the hydrocarbons it eats to power itself, emitting CO_2 and water, and humans have learned to combust the hydrocarbons with oxygen to provide thermal energy from which heat and useful work can be derived, again emitting CO_2 and water.

Clever humans figured out how to turn some of this work into electricity, which could be easily transmitted to provide heat, light or back into work. In the last century, they also figured out how to turn photons directly into electricity by liberating electrons from semiconductors such as silicon.

Left to its own devices, nature selects for efficiency. Examples, of which there are many, are streamlined fish, streamlined birds with hollow bones and tree leaves shaped for maximising photon absorption in the canopy.

But where there is an abundance of something, humans tend not to worry about efficiency or sustainability. Consider the plight of the 60 million buffalo roaming the North American plains in the late 18th century, reduced by the arrival of Europeans to a mere 500-600 by 1890. Humans have got away with 25 per cent efficient internal combustion engines for wheeled transport for over 100 years, until the damage done by the waste products – CO_2 and local pollutants – became evident, and the need to do something about them for our fundamental survival became clear.

The Stern Report of 1986 categorised the non-inclusion of the cost of waste and emissions in the economics of energy production and use as the greatest and wide-ranging market failure the world has ever seen

The Stern Report of 1986 categorised the non-inclusion of the cost of waste and emissions in the economics of energy production and use as the greatest and wide-ranging market failure the world has ever seen.

The options

The competition to find solutions have boiled down to two or three options for wheeled transport. They are as follows: ICE and net zero carbon fuel; ICE / hybrid and net zero carbon fuel; electrification; hydrogen.

Society tends to evaluate options economically, but the economics of energy supply are very complex – far too hard for an old engineer to fully understand. Politics, subsidies, speculation and taxes, amongst other things, cloud the issue. It is better then in the long term to evaluate and compare by considering efficiency and the sustainability of key resources. To do so can only be rigorously carried out using maths and science. One of the best sources of the maths and science on the subject is *100% Clean, Renewable Energy and Storage for Everything* by Mark Z Jacobson, director of The Atmosheric / Energy Program and professor of civil and environmental engineering at Stanford university.

The book lays out the science, technology, economics, policy and social aspects of the transition to renewable, sustainable energy in clear, easy to understand language. I recommend reading it.

Perhaps then, before we can see why Formula 1 needs AS fuels, we must establish why *society* might need them, in preference to the other options on the table. We will review the relevant issues in part two.

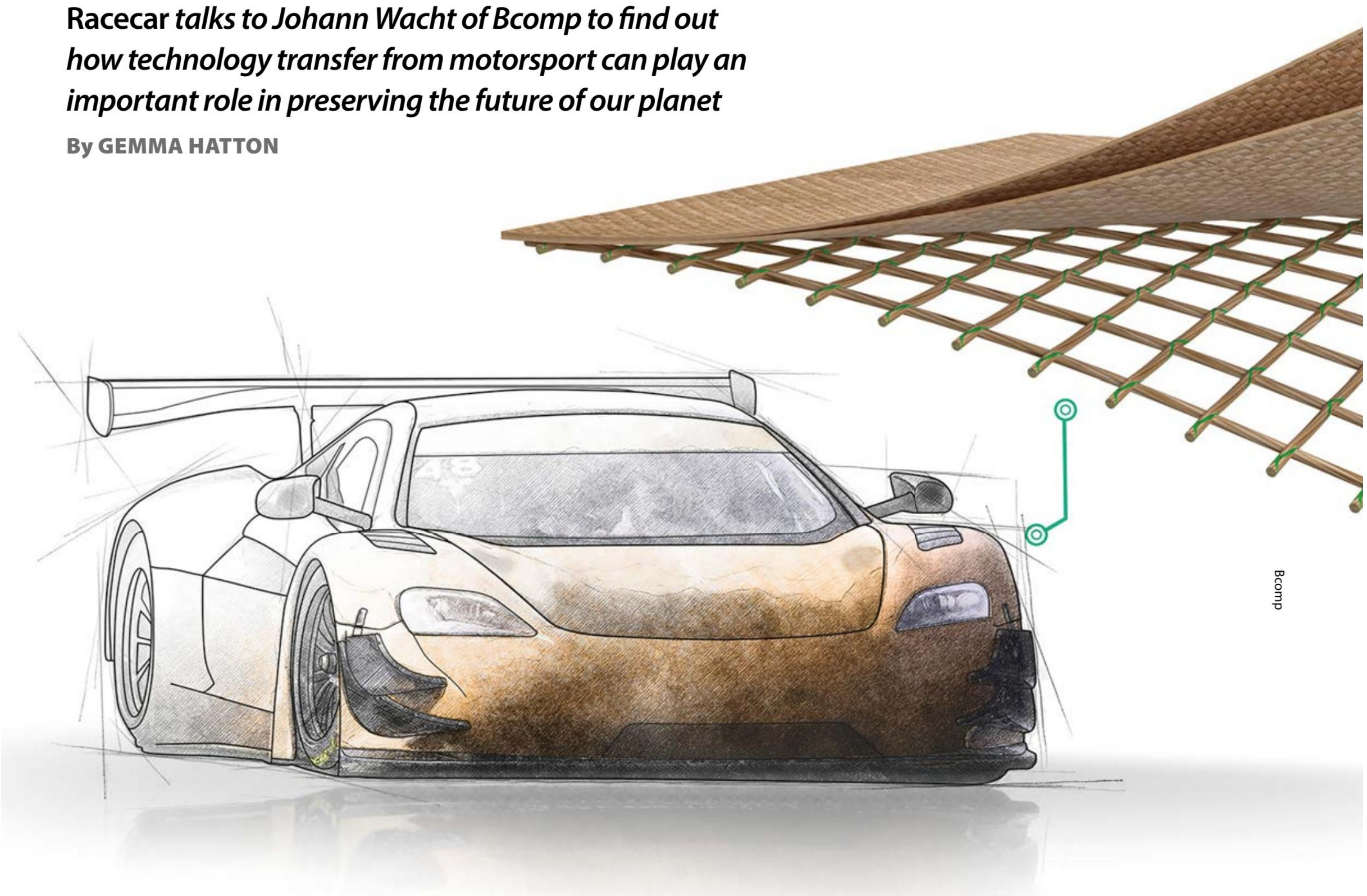
AdobeStock

Left to its own devices, nature selects for efficiency. Examples [include] streamlined birds with hollow bones

Sustainable thinking

***Racecar* talks to Johann Wacht of Bcomp to find out how technology transfer from motorsport can play an important role in preserving the future of our planet**

By GEMMA HATTON



Bcomp

A motorsports bodywork lay up with two layers of ampliTex reinforced on the b-side with powerRibs

If there was anything good to come from the Covid-19 pandemic, it was how quickly the planet began to recover without the normal levels of human activity. While we were locked in our homes, skies became clearer, waterways less polluted and wildlife returned to local areas.

Within a few months of lockdowns, people in the northern Indian state of Punjab could see the Himalayas from more than 100 miles away for the first time in decades. The canals in Venice were blue, and mountain lions roamed the streets of Santiago.

Overall, the global CO_2 emissions in 2020 dropped by 6.4 per cent, which equates to 2.3 billion tonnes of CO_2 that didn't enter the atmosphere. The quick recovery of Mother Nature provided hope during a very dark time, but it also bought into sharp focus the impact we have on our planet.

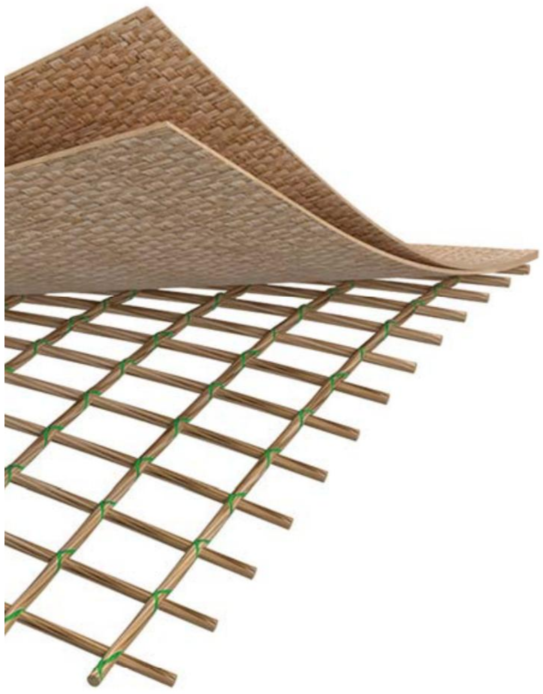
The good news is that since the ordeal of 2020, society has had a shift in mindset. More companies than ever are driving towards a more environmentally friendly future, which has opened the door for more sustainable technologies to be designed, developed and integrated into all industries, but specifically here the motorsport industry.

'When we first entered motorsport, the regulators were mostly interested in the safety benefits of our natural fibre composites,' explains Johann Wacht, manager of motorsports and supercars at Bcomp. 'Unlike carbon, our materials don't splinter, which reduces the risk of punctures.

'But when the pandemic came and people were forced to stay at home with their families, their perspectives changed, and they became more concerned about the future and therefore sustainability. This meant people started to really understand

The technical sweet spot of our natural fibre composites lies in stiffness. We can achieve the same stiffness and weight as an 830gsm monolithic carbon fibre lay up

Johann Wacht, manager of motorsports and supercars at Bcomp



McLaren Racing

McLaren racing seat with Bcomp ampliTex and powerRibs integrated into the structure

Bcomp

AmpliTex reinforcement fabric (dry), showing the natural fibre its made from and two different weave patterns

When we first entered motorsport, the regulators were mostly interested in the safety benefits of our natural fibre composites

Johann Wacht

the added value of our technology and that by integrating natural fibre composites into racecars, not only are you making them safer, you are making them more sustainable, too.'

Natural fibre composites

Bcomp has developed a natural fibre composite using flax fibres extracted from the stem of the *Linum usitatissimum* plant. These fibres are woven together to produce a flexible fabric called ampliTex, which is then impregnated with epoxy resin, similar to a ply of carbon fibre. Different weaving patterns such as bi-axial, twills and uni-directional can then be used to tailor the mechanical properties of the material to suit specific applications.

Flax fibres can also be twisted to form a thick yarn that can then be stitched together to create a grid, called powerRibs. To achieve high stiffness for minimal weight, powerRibs can be bonded to the ampliTex fabric, providing reinforcement and forming a 3D structure on one side of a thin-walled shell element.

'The technical sweet spot of our natural fibre composites lies in stiffness,' says Wacht. 'We can achieve the same stiffness and weight as an 830gsm [grams per square metre] monolithic carbon fibre lay up, making our materials perfect for any semi-structural part that is mainly loaded in bending.

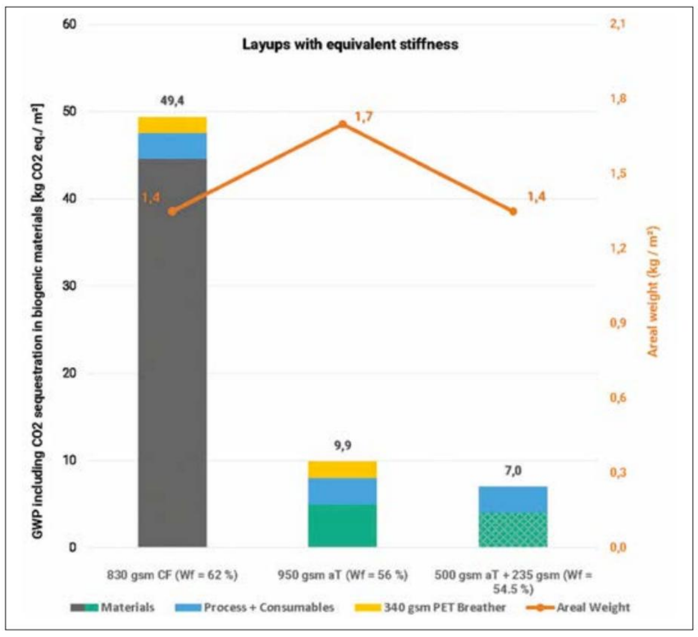
'But if you need high strength, or very high stiffness, then carbon fibre composites are superior.'

Consequently, Bcomp focuses primarily on thin-shelled parts, typically monolithic applications up to 1mm thick / 1000gsm carbon lay ups, such as racecar bodywork. This was first featured on the bodywork of the Four Motors Bioconcept cars, in collaboration with Porsche Motorsport and Fraunhofer, and was so successful that natural fibre composites were quickly integrated into the bodywork of GT4, DTM and Extreme E cars.

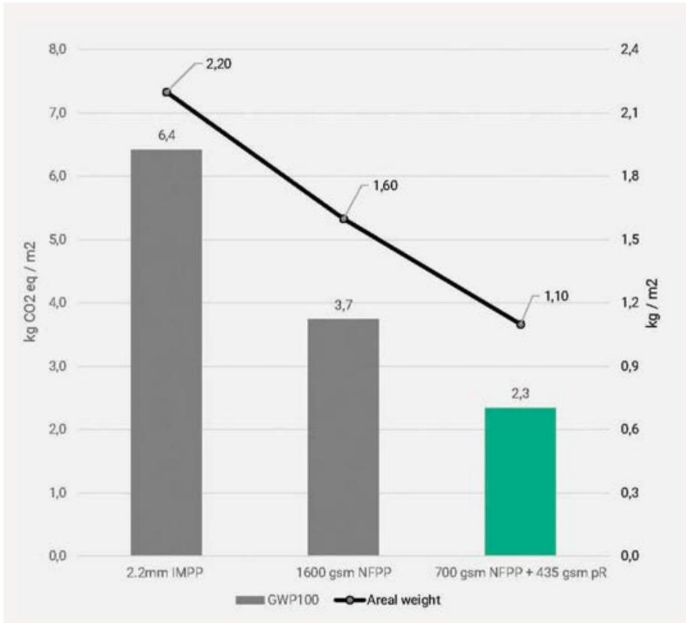
Interior design

Another growing application of Bcomp's product is automotive interior door panels and trim parts. This technique has been adopted by the likes of Polestar and Volvo in their concept cars over the last few years and, by the end of 2022, Bcomp will be supplying the first large scale automotive project in the interior sector.

However, it's not just bodywork and interiors that natural fibre composites are now suitable for. This was proven with motorsport's first natural fibre Front Impact Absorbing Structure (FIAS). This was designed and manufactured by Ycom for a



Carbon footprint of composite lay ups



Carbon footprint of interior panels

formula car and passed FIA crash safety standards in 2020. Although 27 per cent heavier than carbon fibre, the design offers an estimated 77 per cent reduction in material CO_2 emissions, while the overall weight of the car increased by less than one per cent.

If this slight increase in weight is not an option, or the performance requirements are too challenging for a 100 per cent natural fibre lay up, ampliTex and powerRibs can be combined with carbon fibre skins. This approach was used for BMW's iFE.20 Formula E car and the latest Super Formula Next50 cars, which still allowed a natural fibre use of 70 per cent whilst achieving high levels of performance.

Environmental impact

To fully understand the environmental impact of any part, product or material, the carbon footprint of the product's entire life cycle must be calculated. This is known as a cradle-to-grave life cycle analysis, and considers every stage of a product's life cycle, from extracting the natural resources from the ground, through manufacturing and product use, to final disposal.

However, it is extremely difficult for manufacturers to quantify the CO_2 emissions once a product has been transported to a consumer, which is why the majority of companies conduct so-called cradle-to-gate life cycle analyses instead. These consider the part of a product's life cycle from extraction through to the product leaving the manufacturing factory.

To compare the carbon footprint of natural fibre composites with carbon fibre, Bcomp conducted a study that analysed the global warming potential (GWP) of the greenhouse gas emissions from cradle to gate.

Overall, our materials can reduce cradle-to-gate CO_2 emissions by 80 to 85 per cent

Johann Wacht

GWP essentially measures how much heat energy one tonne of greenhouse gas will absorb in the atmosphere, relative to one tonne of CO_2. In this way, the actual impact of a product's life cycle emissions on the planet can be better estimated, rather than just looking at the total emissions. For example, methane has a GWP of 27-30 over 100 years so, if one tonne of methane is emitted to the atmosphere, it would have the same effect as emitting 27-30 tonnes of CO_2.

'Often the bodywork of GT cars consists of a lay up of carbon fibre that is approximately 830 gsm as this gives the required stiffness,' explains Wacht. 'Considering the GWP of the materials, processes and consumables, the carbon footprint of this type of carbon fibre is 49.4kg CO_2 eq/m². Normalising the part size and stiffness, the carbon footprint for the equivalent amount of natural fibre composite using just ampliTex [polyethylene terephthalate] is 9.9 kg CO_2 eq/m², although this material is slightly heavier than carbon.

'But when we use ampliTex with powerRibs, this drops to 7kg CO_2 eq/m², whilst matching the stiffness and weight of carbon fibre. So, overall, our materials can reduce cradle-to-gate CO_2 emissions by 80 to 85 per cent.'

Dr. Ing. h.c. F. Porsche AG

Porsche 718 Cayman GT4 Clubsport MR with natural-fibre composite exterior formed using ampliTex and powerRibs

Dr. Ing. h.c. F. Porsche AG

Close up of one of the interior components of the Porsche 718 Cayman GT4 Clubsport MR made from Bcomp natural fibre materials

Bcomp

A-side of a bodywork section made with Bcomp ampliTex and powerRibs

The same analysis can be done for automotive interiors. Conventionally, manufacturers use thermoplastics such as Injection Moulded Polypropylene (IMPP), which has a carbon footprint of 6.4kg CO_2 eq/m^2. Replacing this with Natural Fibre Polypropylene (NFPP) reduces this to 3.7kg CO_2 eq/m^2. Combining NFPP with powerRibs drops this further to 2.3kg CO_2 eq/m^2.

A natural fibre composite part with powerRibs can therefore achieve up to 50 per cent less weight, 70 per cent less plastic and 62 per cent lower CO_2 emissions compared to standard IMPP interiors.

Carbon emissions

'Ultimately, we need to reduce carbon emissions in any way we can, because every gain we make emits slightly less CO_2 into the atmosphere and reduces the effects of climate change,' concludes Wacht.

'Of course, the ideal solution would be to achieve technologies that are 100 per cent sustainable but, if this is not possible right now, then why not aim for 70, 80 or 90 per cent? We often get challenged over the fact we still use epoxy resin, but our materials still reduce CO_2 by up to 85 per cent on part level compared to carbon fibre, which is much better than nothing, until we find a fully sustainable alternative.

'Natural fibre composites may not be applicable for Formula 1 crash structures yet, but that hasn't stopped McLaren F1 integrating our materials into drivers' seats and pit stands. So I think society needs to think in this way and minimise the environmental impact wherever we can, whilst continuing the momentum of developing sustainable technologies.'

BMW M Motorsport

Manufacturers keen to stress their eco credentials are jumping on board. Here a BMW M GT4 with Bcomp bodywork

The perfect platform

As concern about climate change gained momentum in 2018, there were question marks over the future of motorsport. After all, it encourages people to travel to circuits and watch cars race in circles that are prepared by teams who travel across the world – all for entertainment purposes. However, as has always been the case, racing provides the perfect platform to drive change. Just as manufacturers followed the 'race on Sunday, buy on Monday' model decades ago, the same applies for sustainable technologies today.

'Motorsport has the power to test, develop, promote and scale sustainable technologies to a global audience,' highlights Johann Wacht, manager of motorsports and supercars at Bcomp. 'Often discussions about sustainability in motorsport revolve around the race event itself. Yet all the sustainability initiatives implemented at a racetrack can also be put in place at a football or NBA stadium. The trick with motorsport, though, is that the technology developed on racecars can be *directly* transferred to the automotive industry, and the cars we drive on a daily basis.

'It's this technology transfer to wider society that makes motorsport such a unique platform for developing and scaling sustainable technologies to maximise impact. And why it has such an important role to play in the planet's future.'

Four Motors

It's not just for show either. Here's Four Motor's Porsche 718 Cayman GT4 Clubsport MR in competition with its natural fibre composite interior using ampliTex and powerRibs

Magic markers

What the magic number *really* means, and tying it down with simulation

By DANNY NOWLAN

If you have been in the motorsport business for any length of time, you will have heard the term the magic number. This refers to the percentage of front lateral load transfer distribution at which the car produces the most grip. Like with many things in this business, it's a term that tends to get thrown around like a football, with some people swearing by it and others thinking it is totally irrelevant.

However, if you ever have to construct a simulation model, you are in a very strong position to put some numbers to the discussion. This is the focus of this article.

Here, using a fantastic case study of one of the by products of racecar simulation, we will show how we can use a tyre model derived from actual data to delve into what the magic number actually means.

You have the power

One of my perpetual frustrations with this business is how many engineers seem to have no comprehension of the power of what they have in their hands when they use a racecar simulation package. I have said time and time again that lap time, and the data you get from that, is the full stop at the end of the process. As you are about to see, what you learn in the process of reaching that point is the pay off.

To kick off this discussion, let's return to the most basic tyre model you can have, which is the second order traction circle radius vs load curve fit for a tyre. Mathematically, what we are talking about is shown in **equation 1**. Some typical values for this are presented in **Table 1**.

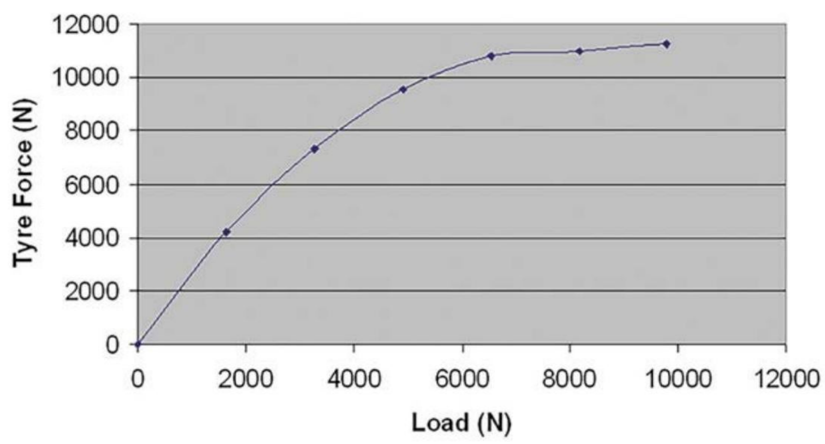
When you plot this out, you'll have something that looks like **Figure 1**.

As we discussed in a recent article about tyre modelling from scratch, using a simulator such as ChassisSim, you can fill in the blanks for this very quickly.

Table 1: Typical open wheeler numbers for maximum tyre force with the coefficient of friction dropping off linearly with load

Parameter	Value
k_a	2
k_b	5.0 e-5 (1/N)

Fig 1: Second order plot of the traction circle vs load characteristic



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

Where,

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

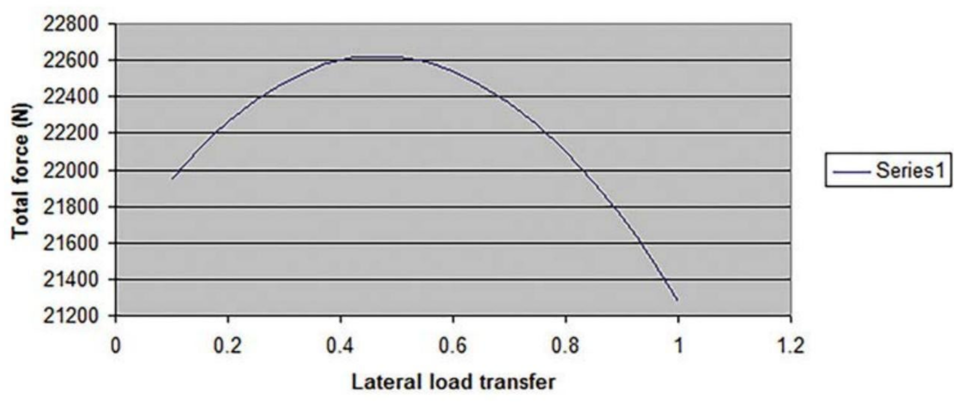
$$\begin{aligned} L_1 &= L_0 + \Delta L \\ L_2 &= L_0 - \Delta L \\ F_y &= k_a \cdot \left((1 - k_b L_1)\cdot L_1 + (1 - k_b L_2)\cdot L_2\right) \\ &= 2\cdot k_a \cdot (1 - k_b L_0)\cdot L_0 - 2\cdot k_a \cdot k_b \cdot \Delta L^2 \\ &= 2\cdot TC_{RAD}(L_0) - 2\cdot k_a \cdot k_b \cdot \Delta L^2 \end{aligned} \qquad (2)$$

$$\begin{aligned} \Delta L_F &= \frac{pr \cdot m_t \cdot a_y \cdot h}{tm} \\ \Delta L_R &= \frac{(1 - pr)\cdot m_t \cdot a_y \cdot h}{tm} \end{aligned} \qquad (3)$$

Where,

ΔL_F = delta load at the front (N)
ΔL_R = delta load at the rear (N)
m_t = total mass (kg)
pr = lateral load transfer (scaled from 0 - 1)
a_y = lateral acceleration (m/s2)
h = c of g height (m)
tm = mean track (m)

Fig 2: A plot of maximum lateral grip vs lateral load transfer distribution



$$F_{yt} = 2 \cdot TC_{RAD\_F}(L_{SF}) + 2 \cdot TC_{RAD\_R}(L_{SR}) - 2 \cdot k_{af} \cdot k_{bf} \cdot \left(\frac{pr \cdot m_t \cdot a_y \cdot h}{tm} \right)^2 - 2 \cdot k_{ar} \cdot k_{br} \cdot \left(\frac{(1 - pr) \cdot m_t \cdot a_y \cdot h}{tm} \right)^2 \quad (4)$$

Where,

F_{yt}	=	total lateral force in N
TC_{RAD_F}	=	traction circle of the front tyre function (N)
TC_{RAD_R}	=	traction circle of the rear tyre function (N)
L_{SF}	=	front corner weight in N
L_{SR}	=	rear corner weight in N
k_{af}	=	front tyre initial coefficient of friction
k_{bf}	=	coefficient of front tyre drop off with load
k_{ar}	=	rear tyre initial coefficient of friction
k_{br}	=	coefficient of rear tyre drop off with load

$$F_{yt} = F_{y0} - pr^2 \cdot (2 \cdot k_{af} \cdot k_{bg} + 2 \cdot k_{ar} \cdot k_{br}) \cdot \left(\frac{m_t \cdot a_y \cdot h}{tm} \right)^2 + 4 \cdot pr \cdot k_{ar} \cdot k_{br} \cdot \left(\frac{m_t \cdot a_y \cdot h}{tm} \right)^2 \quad (5)$$

$$pr = \frac{k_{ar} \cdot k_{br}}{k_{af} \cdot k_{bf} + k_{ar} \cdot k_{br}} \quad (6)$$

$$pr = \frac{e_{TE} \cdot k_{ar} \cdot k_{br}}{k_{af} \cdot k_{bf} + e_{TE} \cdot k_{ar} \cdot k_{br}} \quad (7)$$

$$pr = \frac{0.9}{1 + 0.9} = 0.473 \quad (8)$$

However, where things become interesting is when we take into account lateral load transfer and use **equation 1** to quantify what will happen to the lateral forces on the tyres. For a given load transfer couple we have as shown in **equation 2**.

Given a lateral load transfer factor of *pr*, the front and rear load deltas will be given by that shown in **equation 3**.

At this point in the discussion, you may be thinking, so what? Well, what all this mathematics means is that for a given lateral load transfer distribution, a given lateral acceleration and a given tyre model we can calculate the maximum possible grip for a given cornering situation. Mathematically, this can be expressed as **equation 4**.

Where things become more interesting is when we expand **equation 4**, because it becomes a function of the lateral load transfer distribution. Doing that gives us that shown in **equation 5**.

In this case, the F_{y0} term is all the non-lateral load transfer terms in N. Where it becomes *really* interesting is when we derive **equation 5** by the lateral load transfer term *pr*. Setting this to zero, the lateral load transfer distribution that will give us the most grip is given by **equation 6**.

This is the origin of the magic number and, if you have done the homework using your simulation software to reverse engineer the tyres from race data, you are now in a position to plot this out. This is illustrated in **Figure 2**.

What is even more exciting is that it will tell you the sensitivities of the situation, which in the **Figure 2** case was 1400N. What **equation 6** tells us, then, is the magic number is purely a function of the tyres and what they want.

Rear-wheel drive

However, there is more to this story than meets the eye. In **equation 6** we have considered the tyres purely in cornering. Let's now consider the case where we have identical tyres front and rear, but the car is rear-wheel drive. Let's say we multiply the available force from the rear tyres by a factor of e_{TE}, which is scaled between zero and one. The case of one represent us having all the available traction circle radius for cornering and zero is when it is all used for accelerating. **Equation 6** will then become as shown in **equation 7**.

Now let's put some numbers to this. Let's set e_{TE} to 0.9 and assume the tyres are the same front to rear. Since all the *ka* and *kb* terms are identical, we have **equation 8**.

What this is saying is that for this rear-wheel drive case we want 47.3 per cent of the load transfer at the front. So, for maximum lateral grip, we want the car to have its weight transfer biased to the rear.

However, all of us who have ever run a rear-wheel drive racecar know this is almost certainly a sure fire recipe for disaster.

Unstable territory

What this case study illustrates, though, is that having maximum lateral grip has the potential to push us into unstable territory. Before you all start hitting the rev limiter, remember one of the biggest advances in fighter aircraft design came when designers recognised the performance potential in making their aircraft unstable.

This trend was kicked off by the F-16 and has come to full maturity in the extreme agility designs you see with the Russian Sukhoi Su-35S and Su-57 PAK-FA. They are unstable because that is where the performance is to be found, and it is no different to what we have seen with the magic number.

What will result in the final selection of the magic number is choosing a value that not only gives us good grip, but also satisfies car stability. As a case in point, let's re-visit our rear-wheel drive scenario, but this time plot out the lateral grip with an ellipse factor of 0.9. This is illustrated in **Figure 3**.

Look in the neighbourhood of lateral grip between 0.4-0.5. The lateral grip hardly drops off at all. What this means is we have plenty of room to tune for racecar stability to ensure that not only do we have grip, but that it's *useable* grip.

To quantify this, we will use the stability index, which is calculated in **equation 9**.

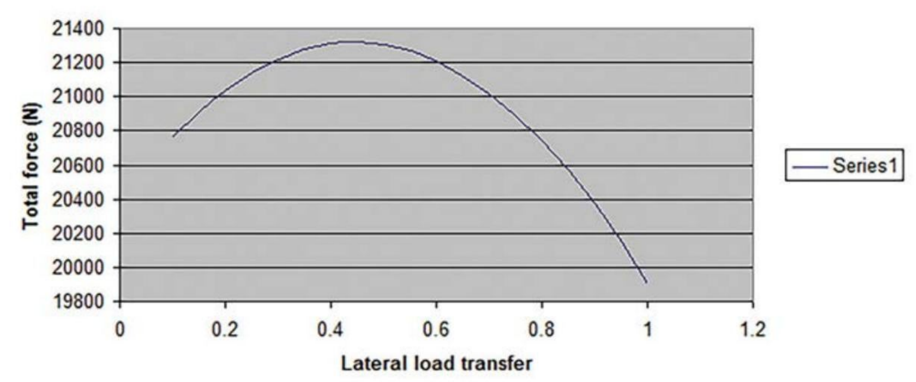
The great news is that $Fm(L_1)$ through to $Fm(L_4)$ is given by **equation 1** and the k_a and k_b terms for all these equations are given to you by using ChassisSim and the process we discussed in detail in tyre load modelling from nothing. The tyre loads L_1 to L_4 are given by **equation 10**.

The last bit in this process is calculating the slip angle derivatives. Fortunately, there are some techniques that can help us along the way here. The first is to get a handle on what the slopes of the normalised tyre force curve look like. There are a couple of approaches you can use, but let me get you started on the normalised ChassisSim slip angle curve that has worked very well. This is shown in **Table 2**.

The last part of the process is choosing which slip angles to take these calculations from. Looking at **Table 1**, you'd be nuts to choose six degrees as the slopes are zero and it makes no sense. Better to set the rear slip angle at five degrees, at which point the front slip angle will be given by **equation 11**.

Bear in mind **equation 11** isn't something that is set in stone. It is an approximation to help you reach an expectation of the relationship between the front and rear slip angles so you can calculate the stability index.

Fig 3: Total force vs lateral load transfer with RWD taken into account



$$C_f = \frac{\partial C_f}{\partial \alpha_f}\bigg|_{\alpha=\alpha_f} \cdot (F_{m1} + F_{m2})$$
$$C_r = \frac{\partial C_r}{\partial \alpha_r}\bigg|_{\alpha=\alpha_r} \cdot (F_{m3} + F_{m4})$$
$$C_T = C_f + C_r$$
$$stbi \approx \frac{a \cdot C_f - b \cdot C_r}{C_T \cdot wb} \qquad (9)$$

Where,

$dC_F/da(\alpha_f)$ = slope of normalised slip angle function for the front tyre
$dC_R/da(\alpha_f)$ = slope of normalised slip angle function for the rear tyre
$Fm(L_1)$ = traction circle radius for the left front (N)
$Fm(L_2)$ = traction circle radius for the right front (N)
$Fm(L_3)$ = traction circle radius for the left rear (N)
$Fm(L_4)$ = traction circle radius for the right rear (N)

$$L_1 = L_{SF} + \frac{pr \cdot m_t \cdot a_y \cdot h}{tm}$$
$$L_2 = L_{SF} + \frac{pr \cdot m_t \cdot a_y \cdot h}{tm}$$
$$L_3 = L_{SR} + \frac{(1-pr) \cdot m_t \cdot a_y \cdot h}{tm}$$
$$L_4 = L_{SR} + \frac{(1-pr) \cdot m_t \cdot a_y \cdot h}{tm} \qquad (10)$$

$$\alpha_F = \frac{b \cdot (Fm(L_3) + Fm(L_4))}{a \cdot (Fm(L_1) + Fm(L_2))} \cdot \alpha_R \qquad (11)$$

Where,

a = moment arm of front axle to c of g (m)
b = moment arm of rear axle to c of g
a_f = front slip angle
a_r = rear slip angle

Table 2: Plot of normalised ChassisSim slip angle derivatives

Slip angle (deg)	Slip angle (rad)	δC/dα
0	0	14.323
1	0.0175	13.925
2	0.0349	12.731
3	0.0524	10.742
4	0.0698	7.9567
5	0.0872	4.375
6	0.1047	0

Table 3: Typical values for stability index based around an F3 car

Item	Description	Value
Fm_1+Fm_2	sum of traction circle radius for the front	5000N
Fm_1+Fm_2	sum of traction circle radius for the rear	7000N
a	distance of front axle to the c of g	1.6m
b	distance of rear axle to the c of g	1.1m
wb	wheelbase	2.7
5	0.0872	4.375
6	0.1047	0

At which point it might be worth a little reminder about how to calculate stability index. Let's illustrate the process using some F3 numbers. This is summarised in **Table 3**.

Let's now say the front slip angle is five degrees and the rear slip angle is four degrees. Using **equation 9** and the derivatives from **Table 2**, the stability index is as shown in **equation 12**.

Let's now reverse the situation and consider the oversteer case, where the front slip angle is four degrees and the rear slip angle is five degrees. Again, evaluating **equation 4**, we see what is shown in **equation 13**.

If we now tie all this together into a process, it shows you how to find the magic number. This is summarised below:

- Using **equations 5-7** plot lateral force vs lateral load transfer.
- The maximum value of this is your start value for lateral load transfer.
- Then, using the stability index, increase the lateral load transfer to reach the desired stability index.
- As a rough rule of thumb here, go for about -0.025.

The great thing about this is it lends itself to an Excel sheet. Simply take the lateral acceleration and speed you are interested in, calculate the front and rear lateral forces and then curve fit the slip angle derivatives.

Finally, using **equation 11**, and keeping the rear slip angle fixed, you can see where the front slip angles are and calculate the stability index accordingly. While this won't be exact, it will get you in the ballpark.

Handling change

To back all this up, I worked through just that process for an F3-type car at a cornering speed of 200km/h and a lateral acceleration of 1.8*g*. The results are shown in **Table 4**.

To say these figures are fascinating is an understatement. As we can see, the peak lateral force occurs at a front lateral load transfer of 0.5. Not surprisingly, the stability index is very marginal at -0.00291. But when we go to a lateral load transfer factor of 0.6, we drop only 80N of force, yet the stability index drops to -0.072. This represents a *big* change in handling.

Table 4: Results of lateral load transfer vs the stability index

Lateral load transfer	Total lateral force (N)	Projected front slip angle (deg)	Stability index
0.1	21952.64	4.24	0.162
0.2	22264.4	4.42	0.13
0.3	22479.4	4.6	0.09
0.4	22597.6	4.80	0.05
0.5	22619.05	5.01	-0.00291
0.6	22543	5.24	-0.072
0.7	22371	5.51	-0.166
0.8	22102.6	5.8	-0.303
0.9	21736.9	6.14	-0.524

$$C_f = \frac{\partial C_f}{\partial \alpha_f}\Big|_{\alpha=\alpha_f} \cdot (F_{m1}+F_{m2}) = 4.375\times 5000 = 21875$$
$$C_r = \frac{\partial C_r}{\partial \alpha_r}\Big|_{\alpha=\alpha_r} \cdot (F_{m3}+F_{m4}) = 7.9567\times 7000 = 55760$$
$$C_T = C_f + C_r = 77634 \quad (12)$$
$$stbi = SM/wb \approx \frac{a\cdot C_f - b\cdot C_r}{C_T \cdot wb} = \frac{1.6\times 21875 - 1.1\times 55760}{77634\times 2.7} = -0.125$$

$$C_f = \frac{\partial C_f}{\partial \alpha_f}\Big|_{\alpha=\alpha_f} \cdot (F_{m1}+F_{m2}) = 7.9567\times 5000 = 39783.5$$
$$C_r = \frac{\partial C_r}{\partial \alpha_r}\Big|_{\alpha=\alpha_r} \cdot (F_{m3}+F_{m4}) = 4.375\times 7000 = 30625$$
$$C_T = C_f + C_r = 70408.5 \quad (13)$$
$$stbi = SM/wb \approx \frac{a\cdot C_f - b\cdot C_r}{C_T \cdot wb} = \frac{1.6\times 39783.5 - 1.1\times 30625}{70408.5\times 2.7} = 0.157$$

$$F_{yf} = 2\cdot TC_{RAD}(L_{SF}) - 2\cdot k_{af}\cdot k_{bf}\cdot\left(\frac{pr\cdot m_t\cdot a_y\cdot h}{tm}\right)^2 \quad (14)$$
$$F_{yr} = 2\cdot TC_{RAD}(L_{SR}) - 2\cdot k_{ar}\cdot k_{br}\cdot\left(\frac{(1-pr)\cdot m_t\cdot a_y\cdot h}{tm}\right)$$

What is even more fascinating, though, is the spread of forces is only about 1000N, or around four per cent. However, we see large fluctuations of the stability index. What this shows is the magic number isn't just about maximum grip, it's about dialling in the handling of the car that you want.

To finish off this month's article, it would be worth discussing the effect of total lateral acceleration on the lateral load transfer number we want. For absolute grip it won't have an impact, but for stability it will. This can be quantified by **equation 14**.

This in turn impacts on the stability index we discussed. Consequently, when incorporating this in an Excel sheet, you need to be entering the lateral acceleration and corner speeds you are interested in.

All that said, everything we have discussed here is for nothing if you have not done your simulation modelling. This is where ChassisSim and its tyre modelling utilities are worth their weight in gold because you can use these tools to find out the k_a and k_b for the front and rear tyres from race data. Without these parameters, you are just guessing.

Once you have this, filling in the details of all of the above becomes a *fait accompli*, which is one of the key reasons any good race engineer would be crazy not to have a simulation tool in their armoury.

Conclusion

In closing, we have discussed the origin of the magic number but, more importantly, how to calculate it. You start from the maximum grip number and then add front roll distribution until you satisfy your stability requirements. Remember, the final number will always be a trade off between maximum grip and driveability, as shown in **Table 3**.

While this won't give you the perfect set-up straight out of the box, it will get you to a very good starting point. However, without the appropriate simulation package to fill in the numbers, this will all be nothing.

United front

In the hotbed of LMP2 and LMP3 racing, United Autosports has found a natural home. It has mixed young and experienced drivers, and is now preparing for greater prototype challenges

BY ANDREW COTTON

The world of LMP2 racing changed beyond all recognition in the FIA World Endurance Championship following the introduction of the new prototypes in 2017. ORECA, Dallara, Ligier and Multimatic were selected as chassis suppliers for the new category and built cars to a new rule set written by the FIA.

Immediately following their introduction, lap times dropped in every round of the WEC. At Le Mans, the improvement from 2016 (3m36.259 in race conditions) with the old car to 2017 (3m28.632) was just the start. Race lap records continued to fall. United Autosports driver, Paul Di Resta, set a record time of 3m24.528 in 2020 qualifying before the FIA stepped in to slow them down.

The introduction of the Hypercar class made things even more complicated as the new cars are slower than the old LMP1s, and manufacturers complained that the LMP2 cars was still too quick. They demanded the LMP2 cars be slowed and the FIA acquiesced.

Through a series of measures, the organising body reduced performance by nominating a single tyre supplier, Goodyear, and specifying to them the required increase in lap time through tyre performance alone. They also took away options for gear ratios, body kits and wings which made the cars less performant, and more difficult to drive; not ideal for a customer-focused category. Not only that, but the measures also placed an increased emphasis on the team to do a better job, and that means delving deeper into the details. To that end, the LMP2 teams have increased their capabilities to whole new levels and, in doing so, the best have made previously perfectly decent I LMP2 teams look average.

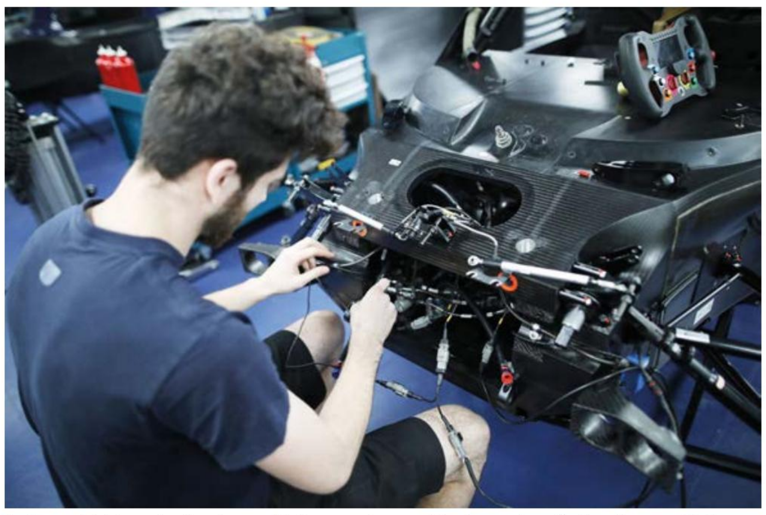
Winning ways

One of those to have risen to the challenge is United Autosports. The Anglo-American team is based in Yorkshire, UK and it has won pretty much all there is to win in the prototype classes of the European Le Mans Series and the World Endurance Championship. The team is co-owned by Zak Brown, a man who made his reputation through a series of sponsorship deals in Formula

There aren't many trophies in the prototype classes of the ELMS or WEC the team hasn't won

Inside the vast packing room, where each programme has its own dedicated bays and inventory sheets

The team is now housed in a new 62,000ft^2 industrial unit outside Leeds, UK


Inside are highly professional assembly bays, a sub-assembly shop and a raft of engineers with the skill sets required to undertake all aspects of racecar maintenance and preparation

The Anglo-American team has won pretty much all there is to win in the prototype classes of the European Le Mans Series and the World Endurance Championship

1 and who is now the CEO of McLaren Racing Limited, and Richard Dean, a former racing driver who has since shown an aptitude for running a race team.

The two are great friends; Brown was even best man at Dean's wedding. Having secured his race licence from the Skip Barber school in the US, Brown wanted to be a grand prix driver, so came to the UK to achieve his ambition. 'Zak came over to do the Jim Russell school, which was a weeks' course, and I was his instructor,' recalls Dean. 'Then, at the end of the course, he was like "I'm going to be a racing driver, I am not going home. I don't know anyone in England, help me."'

Convoluted route

After the collapse of his Vauxhall Lotus deal in Europe, Brown found himself sleeping on the sofa at Dean's sister's house as he had nowhere else to stay, and his former race instructor was in the process of moving house himself.

They stayed in touch as their respective worlds righted themselves, and eventually they decided they should start their own racing team. Both had found themselves making a new start in the UK, and figured they could work together.

'I had worked with Lawrence [Tomlinson] setting up the Panoz [GT project], and then, when he bought Ginetta, I started running that company,' explains Dean. 'I revamped the junior series, got it onto the British Touring Car package, and ended up sitting on the board as MD of one of Lawrence's successful companies, listening about care homes and construction, thinking how did I end up here?

'Zak had opened his London office and was thinking about moving to the UK with his family. We had always kept in touch, but were doing separate things. One day I was moaning to him about how I wanted to get back into the competitive side of motorsport. Zak said he was moving to England, and that he was doing the Ferrari Challenge, so we said let's get an Audi GT3 car and a truck.

'We decided to set the team up, and called it United Autosports because of the United States and United Kingdom, and because we couldn't think of anything better. We paid £500 for the website domain and logo and that was it. We did some British GT races, and then it took off.'

The team started GT racing in 2010, running Audis and then McLarens and were immediately successful. They lined up star drivers at Macau and finished up with a run of three podium finishes at the Macau Grand Prix. They took on a British Touring Car Championship programme with Toyota Avensis in 2014 and made their prototype debut in 2016 in the LMP3 class of the European Le Mans Series at the Four Hours of Silverstone, claiming the top two places on the podium.

Testament to the team's expertise, the successes kept rolling in. In 2017, United Autosports won the ELMS LMP3 title, and in 2018 finished third at the 24 Hours of Le Mans in the LMP2 class. By 2020, the team had won the LMP2 class at Le Mans, the LMP2 FIA World Endurance Championship title, having

Just some of the vast number of trophies the team have won in the prototype classes of the ELMS and WEC

switched from a Ligier to an ORECA chassis, and both the LMP2 and LMP3 classes of the European Le Mans Series – in the latter class multiple times.

Brown's influence is clear; at the Daytona 24 hours in 2018, the team ran Fernando Alonso in the same car as Lando Norris, further establishing the team's reputation for hiring top-level drivers.

Rules of the game

Rival teams had no choice but to up their game to compete and, as they were doing so, behind the scenes the FIA and the ACO were changing the rules of the game once again. Mid-way through the new LMP2 era, the organising bodies announced their new Hypercar category. Following a few missed steps, they also decided to include in their top class IMSA's LMDh formula.

The LMDh formula follows the lines of the outgoing DPi class, with the LMP2 base used by a manufacturer that needed only to supply an engine and bodywork. The Hypercars and LMDh cars will be performance balanced.

That was the key that unlocked a multitude of commitments, and a number of announcements were subsequently made, including Porsche, BMW, Cadillac, Acura and Lamborghini. There are others coming but having so many manufacturers commit in a short space of time was a golden carrot on the end of a very short stick for the competing WEC LMP2 teams.

Teams have the opportunity to step up to the top class with a manufacturer, or as a private team with backing. For those already competing in the series they were instantly more attractive to prospective partners.

Although the prototype hybrid technology is less complicated than the old LMP1 cars and far more in line with the LMP2 cars, it is clear that competing in Hypercar is a whole different ballgame to LMP2. Assuming the BoP works, the performance differentiator will be off track, and teams therefore have to be at least as good as the factory teams from Toyota, Peugeot, Porsche and Ferrari.

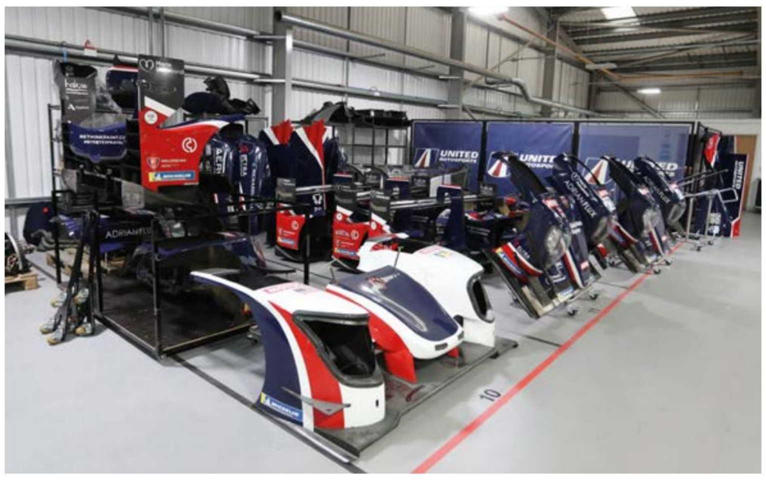
With more than 10 years in the WEC and with Le Mans conquered, as well as two years of running the GR010, Toyota is the team to beat. Such is its depth of expertise that any team will have to take a major step to do so.

That knowledge has not affected the marriages of LMP2 teams and manufacturers, however. The WRT team, which made a name for itself in GT racing with Audi, recently landed the BMW WEC deal after its long-time partner stopped its programme to focus on Formula 1. Bobby Rahal's team will run the BMWs in the US. The Iron Lynx team, partnered with Prema, entered LMP2 in order to learn the WEC circuits to run the Lamborghini project. Likewise, Roger Penske ran an LMP2 programme in the WEC before landing the Porsche deal,

The race suits mounted on the walls of the factory serve to remind visitors of the reach of the team, and its top management, as well as its achievements over the years

Assuming the BoP works, the performance differentiator will then be off track, and teams have to be at least as good as the factory teams from Toyota, Peugeot, Porsche and Ferrari

At the Daytona 24 hours, the team ran Fernando Alonso in the same car as Lando Norris, further developing its reputation for hiring top-level drivers



In the car assembly bays, each programme has its own dedicated area with the parts for every car catalogued and safely stored, ready for when they're needed

and customer cars have been sold, with JOTA putting together a deal to compete with the Porsche 963 as a privateer.

Golden ticket

Further deals have been done around the paddock but, despite its record in LMP2, United Autosports is the only one of the likely LMP2 outfits yet to win a manufacturer contract. It hasn't even been linked with one, although clearly it has come close to one of the golden tickets.

'They all go back to pre-existing relationships, so Penske and Porsche, they ran the LMP2,' notes Brown when asked why not United Autosports, yet. 'They also ran the Grand Am. Then you get into AF Corse and Ferrari, they have always been Ferrari's team. Then BMW with Rahal, Rahal has always been with BMW. Likewise, Cadillac with Ganassi. Even WRT were tied into Audi, and there is a connection to BMW.

'JOTA is a one-car customer programme paid by a sponsor, so that is not a manufacturer works deal. [Prema] is not really an LMP2 team, that was purely a team that got a works deal.'

Due diligence

There is an obvious personal connection between United Autosports and McLaren, as Brown has a foot in both camps. However, his involvement with both companies might actually make it harder for United to land the deal if, or when, McLaren pulls the trigger and commits to Le Mans.

'Talking to other manufacturers, in some instances they have assumed we are going to do a deal with the relationship I have with my other hat on,' admits Brown as we talked in a meeting room at the United Autosports workshop. 'It has been a hindrance in some instances. When, or if, McLaren decides to come on they will have to do proper due diligence. The good news is that United's CV is pretty good, so I like to think that Richard would welcome due diligence on the race results, the factory, who works here, the foundation of the racing team and the financial stability of the racing team. Those are the things you are looking for.'

Regarding McLaren's entry, the British company has long been part of the discussions for Hypercar, but other projects have ultimately taken precedence.

'It is really about McLaren being in a good place with all its other racing programmes,' admits Brown. 'Does the new racing series fit our brand? Is it not an operational distraction specific to our Formula 1 team? That's why we bought an IndyCar team that is based there. That's why we acquired the Mercedes Formula E team. What we cannot do is distract our core product. It has to financially stand on its own two feet. I don't take Formula 1 money to share with IndyCar, for example. It has to be commercially viable.

'The WEC fits our brand. There are ways that you can do it that would be operationally distracting and ways that are

To compete in the LMDh category, teams have to be prepared to take on the manufacturer outfits. That means the highest levels of professionalism in every aspect of the business

not operationally distracting, which is why some outsource to a team, while others do it in house. Financially, that is sponsorship, and the WEC is sellable. Are we fan of the championship? Yes, we are. It ticks all the boxes.'

Operation expansion

In preparation for an anticipated deal with McLaren or another interested party, the team has moved to a 62,000ft^2 facility outside Leeds, UK and is currently expanding its floor space. Having outgrown its original office quickly, it added building after building before management decided to bring the whole operation under one roof.

Housed within this impressive new facility, in which every aspect of running a racing team have been considered, are the LMP3 and LMP2 cars, as well as a collection of historic cars that run in historic events around the world. That side interest has blossomed into a successful customer historic racecar restoration business in its own right.

Be prepared

With the workshop in place, a highly successful engineering team already employed, it's hard to see how the team could step forward, but in mid-September it employed Jakob Andreasen from Toyota. The appointment of Andreasen, formerly chief performance and operations engineer at Williams, and chief race engineer at Force India, having also worked for McLaren, is an indicator of where the team expects to be when, or if, it lands a Hypercar deal.

'The competition gets bigger every year, and Richard and United have kept up but, from what I have seen of LMP2, the competition is fierce, and the detail you are looking for to make the difference is harder to find,' says Andreasen. 'As soon as I met with Richard, it was clear that this was a significant opportunity that I wanted to be part of. For sure I don't expect to go in and say it all needs changing. Clearly it doesn't. There's already a good structure in place, a good core, and it is about identifying the core skill sets and making sure we add to the skill sets and build on what is already there.'

Subtle work

'The other thing I am quite keen on is making sure people are able to fulfil their potential. I very much enjoy working with the young guys, to make sure they have everything they need in their career to progress. They get better, move on and support the business. That process is quite long and detailed, but it's subtle work that needs to be done.

'We need to win in LMP2, support the business and make sure it is delivering,' he continues. 'It is always about staying one step ahead, and making sure we have everything covered.'

Dean, meanwhile, continues to focus on preparing the team for the top class. 'I don't want it to take us by surprise,' he says of a hoped-for deal. 'It is a daunting project, but we don't want it to be an overwhelming one. [We] need to be ready now so we can say we can take this on, we are ready for it, and we can do it justice.'

'There's a good structure in place, a good core, and it is about identifying the core skill sets and making sure we add to the skill sets and build on what is already there'

Jakob Andreasen, Technical Director at United Autosports

Currently, United Autosports is like a coiled spring, all prepared and ready to go for when an LMDh deal comes its way. As the team itself put it, it's not a case of if, but when, and with whom…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IN BRIEF

Lamborghini has confirmed its LMDh engine will be a 90-degree, twin-turbo V8 that is being developed in house at **Squadra Corse.** Lamborghini's LMDh car will make its race debut at Daytona in 2024, with the spine of the car built by French company, **Ligier.**

ExtremeE has announced it will allow a sixth member to join teams on event, provided they have less than one year's experience in professional motorsport in order to help young team members learn the ropes. The change comes following the Hamilton Commission report that aims to accelerate the employment of under-represented minorities in motor racing.

Ginetta has reached a deal with the SRO to support the British GT series in 2023. The British-based constructor will run three championships on the schedule, the Ginetta Junior Championship, GT Academy and GT Championship.

Ford has confirmed it will return to Le Mans for the first time since the end of the GT programme in 2019, competing with customer teams in the WEC and at the French endurance classic from 2024. The company will not be able to compete as a factory team in GT, though, as it does not have a Hypercar programme.

However, Ford will compete in IMSA's GTD Pro class, the primary target for the brand, with the Mustang GT3 car that is currently under development with Canadian company, Multimatic.

The FIA has nominated Siemens to be its 'Official Sustainability PLM Software Supplier'. The company will support the FIA's sustainability efforts across all of its championships, including Formula 1.

The Siemens Xcelerator portfolio will enable the FIA to design vehicles and regulations to reduce energy consumption and emissions, supporting the FIA's sustainability goals.

Porsche pulls plug on F1

Porsche has pulled the plug on its deal with Red Bull GmbH to partner in Formula 1. The German manufacturer, part of the Volkswagen Group, had intended to buy into the Advanced Powertrains division of the company, taking over from where Honda leaves off for the new powertrain regulations that come into force in 2026.

In a statement, Porsche indicated that it expected parity in both the powertrain and team departments of the Formula 1 team, but that seems to have been the sticking point.

'The premise was always that a partnership would be based on an equal footing, which would include not only an engine partnership but also the team,' read Porsche's statement. 'This could not be achieved. With the finalised rule changes, the racing series nevertheless remains an attractive environment for Porsche, which will continue to be monitored.'

It is hard to see how Porsche can now join the Formula 1 grid without significant extra investment. The company could set up its own team, but would need to start from scratch, likely within its Weissach facility, and would also need to pay the entry fee to the series.

It could purchase another team, such as Aston Martin or Williams, but this would also require extra investment on their part.

The power unit deal with Red Bull would have seen it gain a head start in terms of a facility, knowledge and staff in the UK, and this would now need to be built from nothing.

Meanwhile, Audi is rumoured to have taken a majority shareholding in Swiss team Sauber, and is in the process of starting its engine programme. Both brands have promised parent company, VAG, that the F1 programme would provide a revenue stream, although with the plans in place for Audi, and with no plan in place for Porsche, it is hard to see that happening at all.

Catesby is GO

The 2.7km Catesby tunnel, formerly a railway tunnel that has now been converted to a full-scale road and race car test facility, was christened by the Multimatic-run Mazda DPi car that was driven by Andy Priaulx.

Multimatic ran the car through the tunnel to correlate data previously gathered from 40 per cent scale testing and full-size wind tunnel testing, as well as CFD, before putting the tunnel to further use.

Originally designed to conduct real-world production car testing, the facility ideally lends itself to racecar testing and development as well.

The full story of the 8.2 x 7.8m x 2.7km tunnel was carried in *Racecar Engineering* V24N11.

The first racecar through the Catesby tunnel in Northamptonshire, UK was the Multimatic-run DPi driven by Andy Priaulx. The disused railway tunnel offers both a road and race test facility

OBITUARY – Mike Blanchet

Racecar Engineering was saddened to learn of the passing of our contributor, Mike Blanchet, on September 7. Mike died shortly after his wife, Pat, whom he cared for in the later stages of her life, giving up his regular monthly column in this magazine to do so.

Mike claimed not to have been a writer, and was unsure about how many columns he could turn out in a year. We agreed to start him off with a relatively easy schedule, but he wrote reliably and well pretty much every month since the December 2012 edition.

His columns for *Racecar Engineering* were insightful, and often ahead of their time, his view of racing born from years of passionate involvement in the sport. He was as comfortable putting a literary arm around someone who needed it as sending a torpedo into a driver, team owner or manufacturer that deserved it.

Mike spent many years as the joint managing director of Lola Cars when, at its height, it was a powerful player in IndyCar, the world's largest manufacturer of racecars and a hotbed of young engineering talent that was carefully nutured by the British company.

A former racer himself, Mike spent more than 20 years at Lola, first as head of sales and then as joint managing director. He left after fundamental dissents with owner, Eric Broadley, about the wisdom of taking Lola Cars into Formula 1 as a team. Mike's concerns proved well founded, as Lola soon after fell into administration.

Mike then moved to RML, and later set up as a motorsport business consultant, responsibilities including the European division of Honda's Mugen engine operation. His idea of relaxation was to take the wheel of his Porsche 911 and drive it flat out around the roads of Norfolk.

Mike Blanchet 1948-2022

Audi tests for Dakar

Audi has developed its RS Q e-Tron in preparation for the Dakar rally, which starts on 31 December, and completed final checks by competing in the Rally du Maroc in early October

The new car marks the second phase of the German manufacturer's development programme and does not carry over a single body part from its predecessor. The cockpit is wider, the front and rear upper bodywork has been redesigned and the airflow concept through the engine bay has been reworked.

'The aerodynamic aspect should not be underestimated in desert rallying,' says Axel Loffler, chief designer of the RS Q e-Tron. 'The new cockpit dimensions mean the body has a larger, and therefore less favourable, cross section, but it was still possible to reduce overall aerodynamic drag by around 15 per cent.

'The improved airflow further reduces the energy requirements of the electrically-powered car.'

Audi RS Q e-Tron Mk2 made its race debut on the Rally du Maroc but has Dakar in its sights

The drivetrain uses an energy converter comprising an internal combustion engine taken from Audi's DTM programme and a generator, as well as a high-voltage battery and two electric motors, one on each axle.

The electronic control system is a first in rallying and presented challenges on the car's debut, notably a surplus of short-term power when the wheels were out of contact with the ground.

The FIA rules now intervene at 2kJ of excess energy and impose sporting penalties, which has led to a lot of development work on the power controllers.

Further work has also been undertaken with ancillaries such as the servo pump, air conditioning system and driver comfort and accessibility to the computer programmes drivers need during the competition.

Robyn takes FIA CEO role

The FIA has appointed Natalie Robyn, a former senior manager at Volvo, Nissan and DaimlerChrysler, as its first ever CEO.

Robyn will be responsible for the successful operation and financial performance of the FIA administration, as well as driving the overall strategy to deliver the leadership's vision of reform for the Federation. Robyn will also develop new commercial growth plans to increase and diversify the FIA's revenue streams.

'The appointment of Natalie Robyn as our first ever CEO is a transformative moment for our Federation,' says FIA president, Mohammed Ben Sulayem. 'Her extensive experience and leadership will be crucial to improving our finances, governance and operations. She has a proven track record of delivering diversification and growth, as well as developing executive leadership capabilities.'


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Overlords

Power to the people, but not the people in charge

A few months ago I wrote about my objection to the FIA dictating whether or not teams had to link with motor manufacturers to enter the top class of the FIA World Endurance Championship. Teams took on the challenge and linked with the most spurious of companies in order to gain an entry, for no apparent reason than the FIA demanded it.

Meanwhile, in IMSA, teams have been denied entry into the series because the motor manufacturer is not considered worthy of an entry. This, I said at the time, is over reaching the governing bodies' remit in motor racing. Who are they to judge whether or not a competitor is ready to race? Their remit is to ensure the regulations are competent, and that the cars are safe. That is it.

Now, however, the FIA has extended its decision making further still into the driver market, and denied Colton Herta a chance to drive in Formula 1 as he does not qualify for a Super Licence. This is a multiple race winner in the US, a driver who is as comfortable in powerful single seaters as he is in a GT car or a prototype, as proven by his two class wins at the Daytona 24 hours. Anyone who takes a wider interest in motor racing and is prepared to switch disciplines is worthy, I think, and it should not be the job of the FIA to deny the chance to a professional driver.

IndyCar took a slightly different route, allowing Herta to race in 2019, and he became the youngest ever race winner at the age of 18. He has won races every year since in IndyCar. However, F1 being what it is, he is deemed not to qualify, and an overhaul of the system has been called for. It is hard to fathom the FIA's thinking in this matter.

The FIA should look to how young driving talent is being denied a place on the F1 grid and address that issue

The Super Licence is there to maintain professionalism among the drivers – rent-a-drivers need not apply – but how that reasoning could apply to someone of Herta's experience, and obvious skill, is bizarre. The FIA should look to see how young driving talent is being denied a place on the F1 grid and address that issue as a matter of urgency.

Following the confirmation of the 24-race F1 season for 2023, there was consternation around the rest of the racing world as established race dates were bumped. The Spa 24 Hours, held since 1953 at the end of July, has now had to move to the start of the month due to the Belgian GP being staged on its traditional weekend. The promoter must have suggested the date, and the FIA approved it, but to Stéphane Ratel it made no sense to drop a race and date that doesn't cost the local community a penny, and replace it with one that does. Ratel, being the businessman he is, mollified his teams by suggesting they sell on their rooms to F1 teams at vastly inflated prices, and make money.

The move to 24 races in a season means more of a strain on the Formula 1 teams. As the FIA's Robert Reid pointed out when he attended the WEC race at Spa in May, having worked in the pub industry in Scotland, it makes sense to open for five days with one shift, or seven with two shifts, but it never makes sense to open for six with two shifts.

Formula 1 has now reached the point that it needs to at least consider a second shift of mechanics and engineers in order to prevent burnout. The majority of the team don't travel first class, or on private jets, they don't get time to recover between races with back-to-back races, particularly if there is accident damage to contend with. They each have to travel as far as everyone else (84,000 miles if you don't fly home between races, according to one website) to complete the season. The fact remains that Formula 1 is more powerful in Europe than any other series, and its expanding schedule is coming at a substantial cost.

The SRO is trying to avoid its own date clashes with others in the same marketplace, such as the DTM, the French and British GT series and the ADAC GT Masters to allow its teams to compete in more than one series and still make a living. Moving the Spa date was something of a headache.

The ACO actually put out a statement thanking the FIA for *not* having a race clash with its centenary of the 24 Hours of Le Mans in June. That's the power of Formula 1 and the effect that it has on other racing series in Europe. There will still be a date clash on the Le Mans test weekend for drivers competing in the SRO's GT World Challenge Endurance at Paul Ricard on Saturday night. That poses a problem; the drivers need to be in Le Mans for signing on while the GT race is going on. Last year 50 drivers, from IMSA, the SRO and other series missed Saturday's signing on, and were fined €3000 each. That's an impressive €150,000 in fines for a simple date-clash.

That aside, the ever-increasing Formula 1 calendar is having an effect on its teams, their personnel and other racing series. We have to see what the long-term effect is, but it may well be that F1 needs to back off a little to protect what it, and everyone else in European professional motorsport, already has.

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Subscription rates
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Europe (12 issues) £100/€120
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Email info@seymour.co.uk

Printed by William Gibbons
Printed in England
ISSN No 0961-1096
USPS No 007-969

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