TESTING TIMES CALL FOR TOP FACILITIES

Aero is fast becoming a more important factor in Sprint Cup, and teams are facing major changes in the way they work as a result

SAM COLLINS

A Generation 6 Chevrolet being put through its paces at the Aerodyn facility in Mooresville, NC – a tunnel that was purpose-built for stockcars

Engineers working on a Generation 6 Ford in the ARC tunnel in Indianapolis – one of only two scale model wind tunnels used regularly by Cup teams

At the 2014 Daytona 500, the Hendrick-built Chevrolet SS of Dale Earnhardt Jr was involved in a thrilling two-lap dash to the finish, but an engineer's thoughts were inevitably drawn to a flapping bit of tape on the front of the car. How much drag was it creating?

Aerodynamic discussion dominated the Fox Sports commentary of the weather-interrupted race. Did the Toyota arrive in a higher downforce, higher drag trim to take advantage of traffic? Were the Chevy's running very low drag to qualify well? Without access to the team's aero data it is hard to know for sure but, it is certain that aerodynamics are increasingly key factor in top class stockcar racing.

At first glance that may seem obvious, but over the years -despite substantial investments in testing facilities and technology – more effort has gone into the mechanical performance of the cars.

This is something that stacks up when you look at the number of wind tunnels in use in NASCAR compared to the number used in F1. In grand prix racing, all but two of the teams have their own wind tunnel – and indeed some teams have two. On top of that there are a handful of commercially available tunnels largely dedicated to F1 testing, with more than 15 tunnels working on the open wheel designs. In comparison, in Sprint Cup there are only six facilities in common use, including the Laurel Hill Tunnel.

Now, with draconian new rules in Formula 1 restricting the use of both wind tunnels and CFD clusters as well as a forthcoming cost cap, a range of new technology may suddenly become available to Cup teams. It is notable that the full-scale tunnels currently used in NASCAR are largely fully booked at key times, especially when rule changes are introduced. Two of them – Aerodyn and A2 – are on the same campus in Mooresville, NC, and both have been purpose-built for stockcars. The third – Windshear – was developed not only for stockcars, but also with IndyCar and Formula 1 in mind. It is the largest and fastest automotive wind tunnel in the world.

A2 was always intended to be a the little brother of Aerodyn. It is smaller and has fewer capabilities, but Cup teams do still use it on occasion. However, its big brother is one of the most popular tunnels in the sport. Opened in 2003, the

The Windshear wind tunnel is the largest and fastest facility in the world, and is used regularly by stockcar, IndyCar and F1 teams

A Ford in the Aerodyn tunnel, a facility which boasts 22 fans compared to one big fan found in many other wind tunnels, speeding testing up

AERODYN HARPS SYSTEM SPECIFICATION

1. Main power to the system consists of a single DC power supply rated at 250 Amps and variable 0-20 volts, located in the basement balance room
2. Main power supply is designed to control output voltage to a set point, with amperage generated as required by the load
3. A pair of 1/0 power cables and a small 24 volt control power cable are routed from the basement, up through the left front ram opening into the engine compartment, through the firewall on the passenger side, into the greenhouse, where they connect to the HARPS in-car control box
4. A total of 14 discrete channels are available via connection to the control box located in the passenger side of the greenhouse
5. Each channel has a capacity of 50 Amps, with a total available system capacity of 250 Amps
6. Each channel is provided with a 50 Amp circuit breaker, Push-To-Test switch and Power-On LED to verify proper hook-up and flow direction prior to test
7. System voltage is adjustable from 0 to 20 volts DC. The selected voltage affects all 14 channels
8. System voltage and selection of channels to be "ON" or "OFF" are controlled by the customer using an iPad and a dedicated wireless network
9. Channels selected for "ON" may automatically start and stop in conjunction with tunnel main fans when "AUTO" start is selected.
10. Channel status, channel amperage, total system amperage, and system voltage are simultaneously displayed in real time on the in-car control box, on the iPad, and are recorded in the data
11. For every point of every run, the customer data sheet will record:
- a. Channel "ON" or "OFF" status
- b. Channel amperage
- c. Total system amperage
- d. System voltage

12. In-car control box includes connection for a single 3in duct hose to simulate connection to media electronics packages

"We can prep a car and get through four or five cars a shift – that's ideal for cataloguing"

tunnel has been in a state of constant evolution, and has many interesting design features that make it perfect for the work that Cup teams do.

'We have 22 fans on this tunnel whereas most tunnels have one big fan,' says Chris Osetek, one of the engineers at Aerodyn. 'The problem with one big fan is the deceleration time and acceleration time, but with these small fans it's much faster. One data point takes us 50 seconds, but we have an active ride height control in here which means that if a team was doing an aero map, they can keep running. We can prep a car and get through four or five cars a shift, so that's ideal for cataloguing.'

Cataloguing is the process where teams compare a number of their cars to work out which one to use at particular venues, and to see if any are too draggy to use without further work.

The teams do both cataloguing and development at Aerodyn, but with rule changes in both Cup and Trucks, there will be some more development. Currently, while in a static period of rules, there is more cataloguing according to the teams.

One new addition to the Aerodyn tunnel is the HARPS (high amperage remote power supply) system. It is a fully-automated control system designed to provide control and power to on-car fans including in-line duct, radiator or both. It allows the team using the tunnel to connect all fans to a central connection point, and to control everything remotely from the control room using an iPad app.

'There is a high amp power system, a big box that is mounted in the car, and there is a 200 Amp power supply that comes up from the bottom of the tunnel and the teams hook up all of their duct fans and things like that,' says Osetek. 'If they want them to come on during the test, they just use the iPad to control it.'

There will be one noticeable change in wind tunnel availability this year in North Carolina, and it is all due to the 2014 Formula 1 sporting regulations. In recent years, grand prix teams have been strictly limited on aerodynamic testing, with few straight-line testing days allowed and even fewer tests allowed at full-scale. The only wind tunnel in the world able to really deliver the airspeed at full-scale required by F1 teams is Windshear.

'The Windshear test falls under the designated amount of testing we're allowed to do during the course of a year,' said Lotus F1 team manager Paul Seaby last year. 'The rules allow four days of on-track aero testing, which can be exchanged for wind tunnel testing. We chose to swap all of our allotted on-track aero testing for one big hit of wind tunnel testing. We have done this in previous years and found it to be of significant benefit.

'With so few days allocated to testing, development time is a valuable resource. To get the maximum from it, we pre-fit every new part we're looking to test to make sure it can be changed over quickly. We left a certain amount of kit at the facility in America last time, so the crew has already been out there this week to make sure everything still works, that our software is compatible with theirs, and so on. This is important to make sure that when we arrive we can hit the ground running straight away.'

However, the new rules for 2014 have completely banned full-scale aerodynamic testing, partly due to an accident during an airfield test session in England that eventually proved to be fatal, and partly due to the fear of the costs associated with flying cars from Europe to North Carolina to test. This will almost certainly leave some free time available at the Concord facility.

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The refuge of frustrated engineers that crave a bit more freedom than other classes provide, supermodified racers have a character all of their own

SAM COLLINS

Chris Osetek's supermodified being put through its paces in the A2 wind tunnel

What is the fastest car on a short track? NASCAR Sprint Cup at Bristol? Sprint cars? BriSCA F1? Actually it's none of them. The fastest thing on the short tracks is a Formula little seen outside of a few areas of the USA. Supermodified racing started up in the New York State area and is still popular there, where it is sometimes called the Indy of the East.

One of the promoters of supermodified racing, Bob Gangwer, describes the cars as 'the king of the asphalt'.

'You have to realise that this open wheel racecar is very lightweight, and produces copious amounts of gut-wrenching torque and horsepower. They are rare and exotic beyond imagination. No two are alike, the rules governing them are few and the fans that follow them are as knowledgable and passionate as the drivers are brave.'

It sounds like an excessive amount of hyperbole on the part of the promoter, but in reality it is not. Supermodifieds have become something of a refuge for engineers frustrated by restrictions in other classes of racing. One of them is Chris Osetek, who by day is an engineer at the Aerodyn wind tunnel in Mooresville, NC. He has designed and built a number of cars for himself and others.

'The reason I drive up and down between North Carolina and New York all summer long is because it is a class of racing still open to innovation,' he enthuses. 'The rulebook is very small – a engine capacity rule and some basic dimensions – but then it's really open. It's an open wheel class with huge tyres, huge motors, and the cars weigh in at 1850lbs. All four tyres are different sizes, with the right rear at 18 or 19 inches. We get one race out of the tyres, and they cost $850 a set. '

The engines in supermodifieds are immediately noticeable, not for their design particularly, but for their installation alongside the driver. 'The motor is often offset on these cars and we run 68 per cent max left side weight,' says Osetek. 'Back in the 1980s there were guys doing rear-engined cars and four-wheel drive cars, then the engine ended up on the left and that kind of stuck. The rules say that the engines must be steel block, normally aspirated, run on methanol and be no bigger than 468ci.

'Short stroke, long stroke – you can do what you like, but we run in the 900bhp range whatever,' he adds. 'I have my motor rotated by seven degrees, but some people run them as much as 24 degrees, which can lower the CG height by about a quarter inch. But when you factor in the exhaust installation it ends up being almost neutral.'

The cars have no transmission or gearbox – the engines drive the rear wheels directly, meaning that the cars require a push start. If a driver spins, his race is over. Many cars currently racing use universal joints, but Osetek runs a CV joint, something he believes is worth up to 10bhp at the wheels.

The chassis rules are evidently quite open, but there are some, as Osetek explains. 'It must have a roll cage, but after that it's

The cars feature no transmission or gearbox, and the engines drive the rear wheels directly. If a driver spins, that spells the end of their race

WILLIAM J TAYLOR

There are two classes of supermodified – wing and no wing. However, the no wing cars still feature large aerofoils front and rear

kind of open. A friend of mine did a full aluminium honeycomb monocoque – that did really well. My car has a stressed skin on a tubular chassis, with aluminium bulkheads. Over the years they have tried to keep carbon fibre out because of the cost, but you can get round it as the rule says something like "carbon fibre can only be used for driver safety", which is an easy argument to win.'

There are actually two classes of supermodified car – wing and no wing. That said, the 'no wing' cars still feature fairly substantial aerofoils front and rear. Both classes have substantial downforce, increasing the cornering speed further. 'In the wing class they feature a 24 square foot moveable wing on the top of the car. The wings are not meant to be driver adjustable, but they are passive adjustable so you can design it to flatten out on the straightaway and pop up in the corners. Within the 24 square feet anything goes, so it's pretty huge downforce. Some people use that top wing almost like a drag brake, as we are no longer limited by the aero. In fact we are limited by the tyres which after a point drop off in performance if the load is too high.'

Osetek is reluctant to reveal exact downforce figures, but he has developed his car's aerodynamic package as an after-hours project in the A2 wind tunnel. 'In aero terms it's pretty free. We are at the track, and say we win a race, they weigh us and check the engine capacity – but that's about it. So unless you are doing anything crazy, then it's probably allowed. In aero terms you have boxes to work inside, front and rear wings are open, so are side panels. There is quite a bit of downforce as you can imagine.'

An open rules class such as this is an engineer's dream, but it must be wondered why it has not become more popular over the years. 'None of the cars are the same – that's the cool thing,' says Osetek. 'When you go to the first race of the year you get to see all the new things people are trying. That's the problem – with an open rulebook things can get expensive, but we still get 34 cars per race. But a car less motor will sell for $40,000-$70,000 with people then putting another $30,000-$40,000 on the motor.'

If supermodifieds ever did become more widespread then the costs would almost certainly rise even further, which could spoil the formula.

So it's likely to remain the refuge for any engineers working in NASCAR who want a bit more design freedom, and long may it last! ◆

"The rules say that the engines must be steel block, normally aspirated, run on methanol and be no bigger than 468ci"

Moment of inertia test rigs

The Centroid rig's location next to the Aerodyn tunnel allows teams to run an MOI test before or after any wind tunnel test, saving multiple trips

The rise of simulation technology in motor racing, both multibody and driver-in-the-loop, has placed ever-increasing importance on understanding a car's real moment of inertia and centre of gravity. The first test rig to be revealed that is specifically-built for this task was revealed in 2012 at Cranfield University in England.

The rig itself looks deceptively simple, like a scaled-down version of a child's seesaw. Mounted on an air bed which supports the vehicle, there is an arrangement of steel arms with two long ones running the length (or width) of the vehicle. The rig is capable of being aligned for testing in pitch, roll and yaw, and all three are used by F1 teams like Force India for its calculations. 'We can also calculate the principal moment of inertia and find out which axis the object would like to rotate about,' Dr James Watson points out. 'The centre of gravity is not always on the car's centre line, in either x or y planes, but we assume a symmetry through the car. Certain vehicles like Formula 1 cars are very evenly balanced, so with them it is usually within 2mm of the vehicle centre line, and on road cars it can be up to 10mm off.'

The rig is linked to a computer which logs only three channels of data, including the timing pattern and a force via a load cell. But the results are just what is required by racing teams' vehicle dynamists.

'There is no point in just measuring the moment of inertia on its own though,' Dr Watson adds. 'That would be meaningless – we have to reference it back to the centre of gravity. You can get that in the x and y planes very easily on a flat patch with corner weights, but by using the rig for a supplementary test you can measure the height of the centre of gravity – you simply measure the reaction force in a pitch orientation and a roll orientation. That is simply a case of tilting the vehicle for a set number of degrees and measuring the reaction force at one end – you can then get two values: the centre of gravity height and also any offset from the x or y direction.'

Force India's head of vehicle science James Knapton is in charge of the team's usage of the Cranfield rig, and for him one of the results it puts out is clearly the most important when developing a new model such as the VJM05.

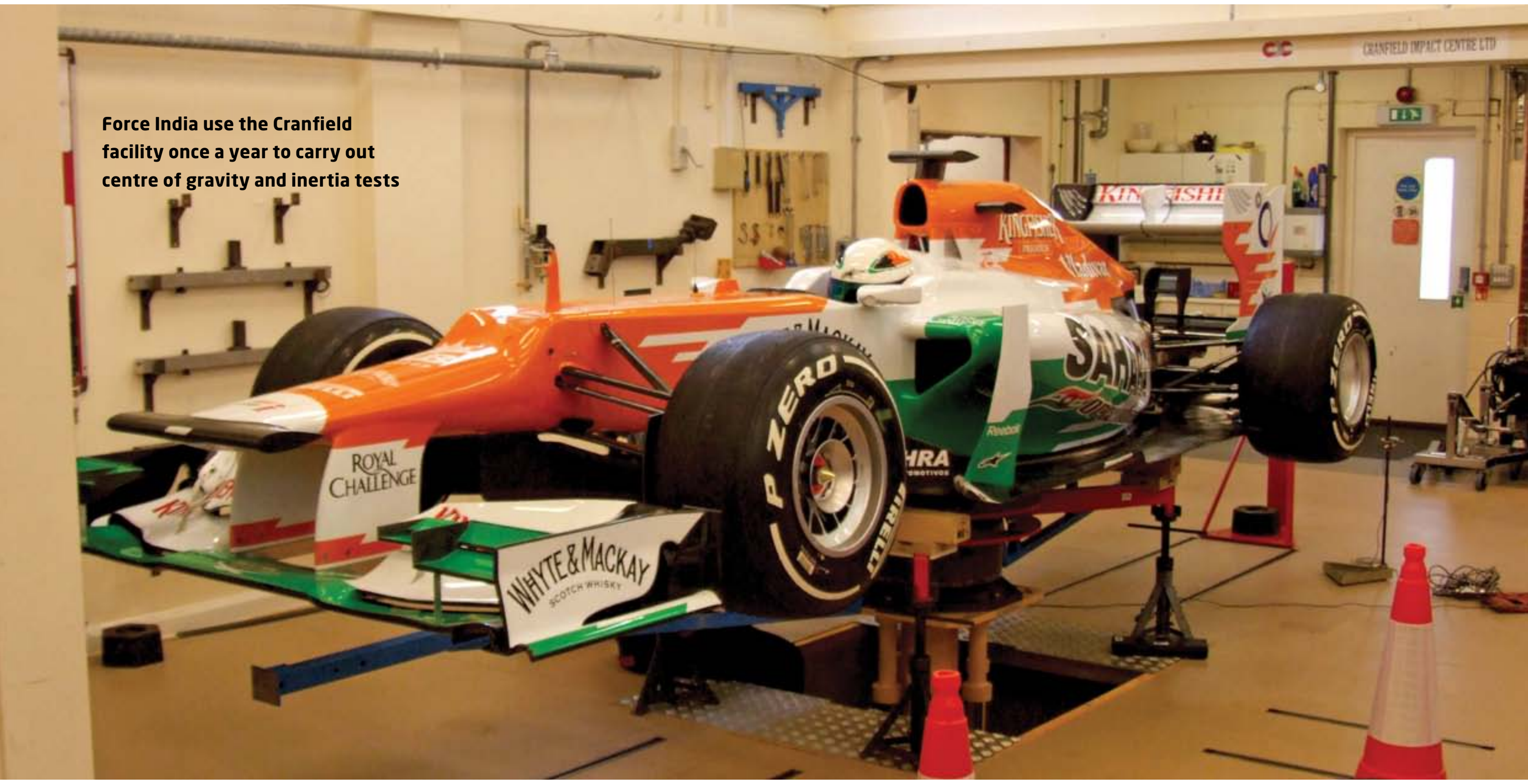
'We go there once a year to carry out a centre of gravity test and an inertia test,' he explains. 'We primarily look at the centre of gravity height, which is massively important in F1. If you change it by 10mm you go about two tenths of a second faster. Over time you may expect the centre of gravity to go down as each new model is completed, but actually it has often gone up which can scare the management. It can be heavily influenced by regulation changes. When the car safety was improved with side panels for driver protection and bigger headrests the height raised, for example.

'The aerodynamicists always want to put things higher too. The chassis has raised at the front over the years as they want to get air under the nose. In the past there also tended to be a lot of winglets on the top of the bodywork and we had to assess whether the gain outweighed the losses from raising the centre of gravity height. But if the rules don't change, you target it to be reduced, and for us it has between 2010 and 2012. It is usually between 200-250mm above the bottom of the car, which is fairly low. We could make it lower still, but we would have to compromise the aerodynamics, by lowering the radiators and sidepods – things like that.'

Beyond understanding the car's centre of gravity height, the inertia of the car is also very important to the team. 'The inertia of the car, how much it resists turning round a corner, is of course the primary function of this rig,' Knapton continues. 'Over the years it stayed roughly the same with

"We can calculate the principal moment of inertia and find out which axis the object would like to rotate about"

"It's important that we have the correct centre of gravity height and inertial properties in our model – it must behave like the real thing"



Force India use the Cranfield facility once a year to carry out centre of gravity and inertia tests

our cars, but in 2009 we started to make the car longer for stability and aerodynamic reasons, and in 2010 the refuelling ban made them longer still, and that changed it a lot. There is not a lot we can do about yaw inertia because the parts of the car pretty much have to be where they are, and we have regulatory limits on weight distribution, which further limits where we can place things. The yaw inertia is usually dominated by things like the front wings and front tyres which are right out at the corners. Our yaw inertia has gone up quite a bit recently, but strangely the drivers don't notice it. You'd imagine they would get out and say it feels very sluggish and unresponsive, but they don't really pick it up.'

In the age of digital simulation, it seems strange that such a simple looking tool is so critical, but what CAD packages output is no comparison to the real world. But the data is crucial to improving the team's digital version of reality. 'We use a lot of the data from this rig in our simulation models, it's very important that we have the correct centre of gravity height and inertial properties in our vehicle model,' says Knapton. 'It must behave like the real thing. We use that data in dynamic models like our driver-in-the-loop simulator – getting the data right means that it feels like the real car for the driver. We had an incident recently where we got the roll inertia wrong, and the drivers were complaining that the car was very strange to drive. We didn't believe them, but later realised that it was out by a factor of 100, due to a user error. The car was oscillating and the drivers picked it up.'

The data also can be used in real-world car development, something Force India technical director Andrew Green has placed an emphasis on.

'We work out the aerodynamic loading on the car via load cells on the pushrods. If we change an aero component, we look at those outings to see if there is any change, but when the car brakes you get a huge weight transfer forward putting load on the front. If you look at the data it looks like there is a massive load on the front. So, we need to compensate that out and to do that we need to know the rate of deceleration and the centre of gravity height. Another way we use the data is if we do stability calculations on the car, and try to work out the yaw moment making the car turn. The front tyres will try to make the car go round the corner while the rear tyres try to stop the car going round the corner looking at that yaw rate sensor of the car. Differentiating that from yaw acceleration we can then divide that by the yaw inertia – and we get the moment acting on the car. We can then use that yaw moment to asses the stability of a change we make to the car.

'The data from the VJM05 and the forthcoming VJM06 will be fed back to the design team to allow them to optimise other parts of the car.

'We use this when we are designing the suspension elements. We need to accurately calculate the load that goes through them. If a wishbone fails at high speed, it is bad – as you probably realise. The data from the centre of gravity height helps us to accurately predict the car's contact patch loads, and that feeds into other models which give us the maximum loads for the suspension. It's especially critical as we don't use very high safety factors, perhaps 25-50 per cent.'

This facility in the rolling fields of England seems a world away from the equally rolling countryside of North Carolina, but in an anonymous building alongside the Aerodyn wind tunnel is 'Centroid'. This is former Hendrick engineer Gary Eaker's equivalent of the Cranfield facility, but it seems far more capable. The team behind it are still a little cagey about its exact specification, though it has been specifically developed with Sprint Cup cars in mind. As is the case with most of Eaker's projects, the technology used in the Centroid rig is all in-house and some of it is very innovative indeed – and according to Eaker, 'pretty difficult to copy'.

Its location next to the Aerodyn tunnel allows teams to run a MOI rig test just before or after any wind tunnel session, saving teams making multiple trips.

The full story on the Centroid rig will appear in the next issue of *Stockcar Engineering*.