Carbon discs and pads still rule the roost in many race series, but with by-wire on the horizon, motorsport braking could be on the cusp of a technological revolution

Anchor men

WORDS BY JONATHAN LAWSON

It's better known as a supplier to the mainstream automotive industry, but Siemens VDO could be about to make a splash in motorsport with a brand-new technology. The company is currently testing a new concept called the electronic wedge brake (EWB), which its inventors hope will have a seismic effect on vehicle braking in general, and motorsport braking in particular.

The principle is that a brake pad connected to a wedge is pressed between the brake rod and the brake disc. The rotation of the wheel and its associated friction automatically intensify the wedge effect, so high braking power can be generated with little energy expenditure. A greater level of control can also be achieved at each wheel.

The man who dreamt up the system is Bernd Gombert, now CTO of the chassis business unit at Siemens VDO. Says Gombert: "The project is going very well. We have the system installed in a production vehicle mule that we are conducting tests on, and we have already recorded shorter stopping distances.

"Motorsport people were among the first to approach us, probably because the EWB

EWB on the dyno at Siemens VDO

has a brake gradient 10 times better than a standard hydraulic system. Maximum brake torque is generated in around 100ms with a standard system. This equates to a distance of 2m at 100km/h – if the time can be halved, a driver can brake 1m later, so in theory, after 20 corners there could be a 20m advantage.” Gombert reckons most recent braking enhancements have made differences measured in centimeters, and to start measuring the difference in meters is really quite special.

Early adopters are likely to be the race classes that are less heavily legislated, so don’t expect to see EWB systems colonizing Formula 1 any time soon. Series more closely related to production vehicles will come first, and Gombert is enthusiastic about the development potential offered

“If braking time can be halved, a driver can brake 1m later into the corner, so in theory, after 20 corners there could be a 20m advantage”
Bernd Gombert

by competitive motorsport: “We are having very interesting discussions with motorsport people at the moment, and we view it as a massive advantage to be able to test the performance and system reliability before we launch with mass-produced consumer vehicles. We will see EWB on the race track before we see it in the showrooms.”

Based on tests so far, Gombert is happy with the design principle, and he sees the next step as miniaturization. Siemens is also using MatLab to run simulations to optimize the system’s algorithms. Next will come further scrutiny of the embedded side of the project, followed by an industrialization study to set out all the production details and liaise with customers. Although Gombert has to remain tight-lipped about exactly who these customers will be, he is able to indicate that a series race car with EWB will be up and running by the end of 2008.

Brakethroughs

Ettore Bugatti is said to have uttered the words, “I build my cars to go, not stop” in response to criticism of his race cars’ brakes. But alongside motorsport’s obsession with speed and lightness, occasional breakthroughs in retardation have occurred. Read on for ‘potted’ highlights.

Girling disc brakes

The 1953 Jaguar C-type (XK120C) earned its place in the history books. Lightweight and with an uprated engine, the car was also impressively braked, by means of all-round Girling disc brakes. This was cutting-edge braking technology for the time, and the car won the Le Mans 24 hours in 1953 in the hands of Duncan Hamilton and Tony Rolt. This victory marked the first time the race had been won at an average of over 100mph. Unfortunately the brakes’ effectiveness indirectly led to tragedy two years later.

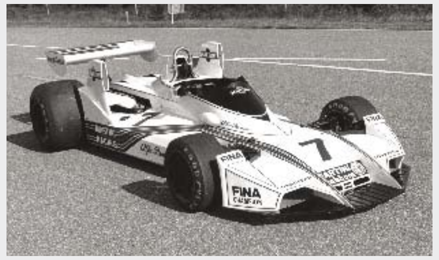
Mercedes-Benz 300 SLR

Based on the 1955 Formula 1 Mercedes-Benz W196 race car, the 300 SLR’s drum brakes struggled at the end of straights, and were inferior to rival Jaguar’s Girling discs, so the team came up with an unusual solution for Le Mans: air brakes, similar in principle to a parachute brake.

The panel behind the driver was mechanically raised while braking, maximizing drag. After braking the panel folded back into place, ready for accelerating out of the corner. Tragedy struck at the 1955 Le Mans when Pierre Levegh’s 300 SLR crashed into the crowd (following an incident caused by inability to match a Jaguar’s shorter stopping distance), killing the driver and 82 spectators in a fire fueled by the magnesium bodyshell.

Brabham’s carbon brakes

Brabham’s technical director Gordon Murray introduced carbon-carbon brakes to Formula 1 in 1976. Initial versions were unreliable, resulting in one bad accident, but by 1979, Brabham had developed an effective carbon-carbon braking system, combining structural carbon discs with carbon pads.



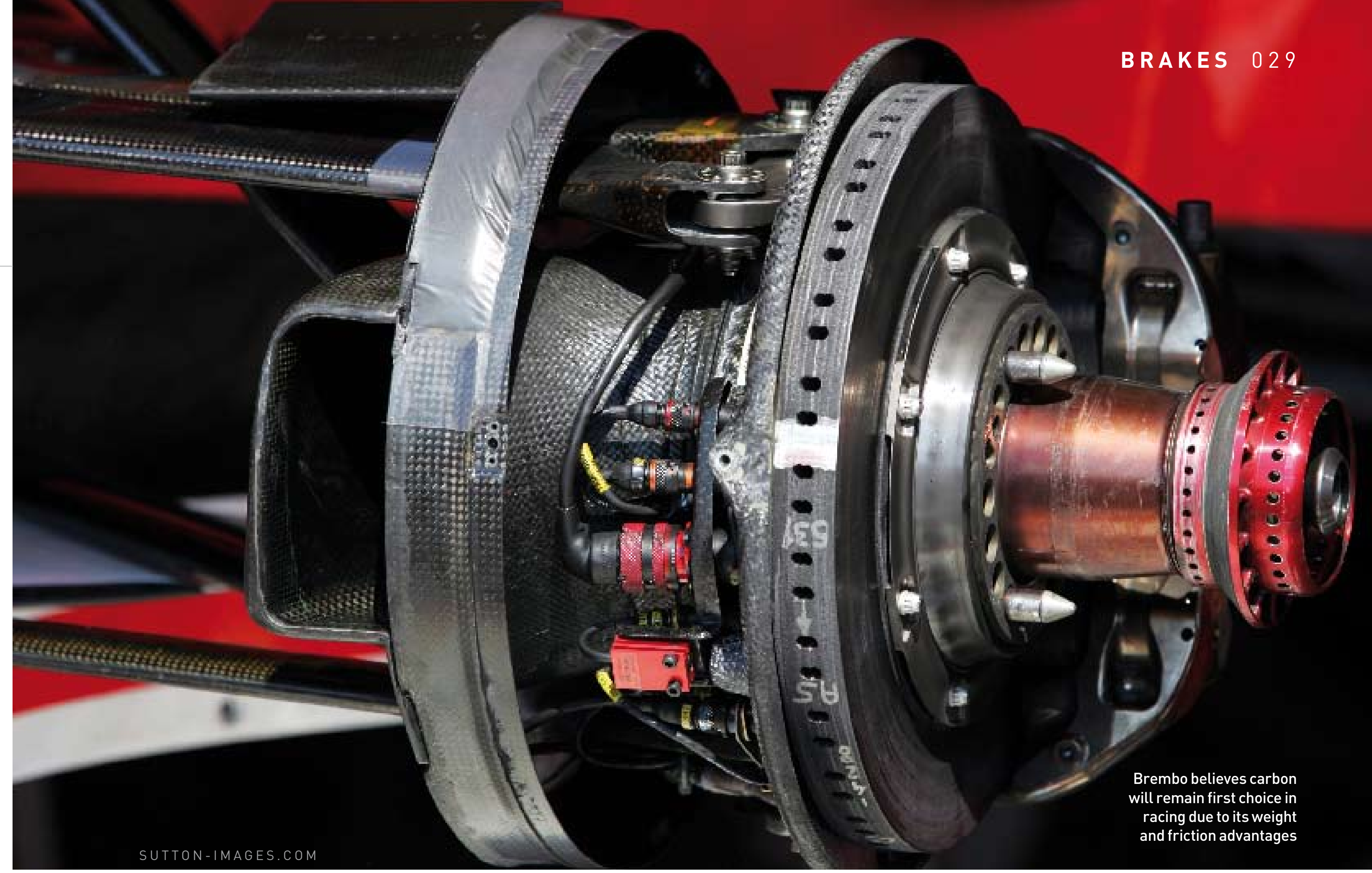
McLaren ‘fiddle’ brake

At the 1997 Austrian Grand Prix it was noticed that the McLarens had a second brake pedal, which could act on one of the rear wheels. This allowed the driver to eliminate understeer and reduce wheelspin when exiting corners, and to slow one half of the car when turning into a corner. In effect, it created four-wheel steering, and was banned.


SUTTON-IMAGES.COM

Cool runnings

Though not a technology development, 1982 brought more brake-related cunning, soon outlawed. F1 teams were permitted to refill cooling fluid post-race. To race underweight, Brabham and Williams installed pseudo-brake coolers. The cooler tanks were empty during the race, and filled up afterwards to make up the minimum weight of 580kg.


SUTTON-IMAGES.COM

Brembo believes carbon will remain first choice in racing due to its weight and friction advantages

When considering the topic of brake-by-wire in general, Gombert is confident that the earlier development issues have now been solved. He says: “Years ago there was the 42V issue – no one was able to generate the high caliper clamping forces necessary with just 12V. The wedge brake design solves these problems.” As for redundancy, crucial for the reliability of any braking application, the EWB could represent a step forward in safety. “If we have a problem with a cross pipe on a conventional hydraulic system and two brakes are lost, control becomes very difficult, a problem amplified by the high speeds of race cars. With EWB, the brakes are independent, so, if a wheel actuator does break down, we still have three brakes left. Redundancy is effectively doubled. Each actuator works by itself,” says Gombert.

Another benefit for motorsport lies in the diagnostics. The status of each brake can be displayed to the driver or pit team via the telemetry. Should a problem with one of the brakes be detected, the others can be boosted up to mitigate the problem. In fact the fine way in which the EWB can be adjusted is something Gombert is particularly excited about. “Let’s say we have a vehicle braking in a corner. The outer, heavily loaded brakes need

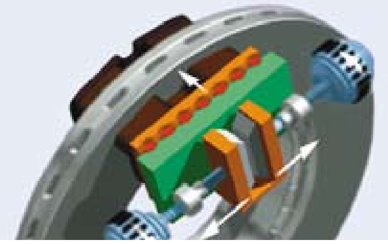
“Take calipers. Each team has specific requirements, and although the rules are strict as regards design and materials, there can be changes in stiffness or weight” *Raffaelo Cornolti*

more brake application than the inner, unloaded side. If the vehicle has a yaw rate sensor, or even a GPS system, power can be given to the side that most needs it. We can design-in an intelligent braking strategy.”

Handbrake use, for example at a hairpin on a rally stage, has not been neglected, and already Siemens is considering how to best harness the EWB. One option is to have a handle on the floor but delete the cable-operated element and replace it with a by-wire operation. Other ideas are on the table, including an electronic control for drifting. As Gombert says, “You can’t stop the rise of electronics in race cars.”

So where does this leave advances in more conventional braking technology? Raffaelo Cornolti, motorsport technical department manager at Brembo, is involved across several different race series, including Formula 1. Brembo provides braking systems for Ferrari, BMW, Toyota and Red Bull, and although Cornolti can’t comment on specific teams, he is able to give an insight into where brake technology is heading. “Take caliper design,” he says. “Each team has a specific requirement, and although the rules are strict as regards the design and material constraints, there are subtle changes in the requirements for stiffness or weight. We design according to team requirements, within the 80GPa stiffness limit outlined in the rules.” The aluminum alloy used has a lower density than many alloys, saving weight. Brembo is conducting tests on other aluminum alloys to see if advances can be made, and one material in particular has been selected for further research. Cornolti won’t say more – other than: “It is so new, we haven’t given it a name yet….” Internal testing is scheduled to finish during this F1 season, and then a decision will be made as to when to introduce it.

As for pad and disc materials, Cornolti believes that carbon will remain the material of choice. For disc design, however, great



Siemens VDO's wedge brake design promises efficiencies that can translate to faster lap times

advances have already been made over the last three years, especially where ventilation is concerned. "The disc is an area where we have found interesting results with temperature reduction and its capacity to dissipate heat. The changes concern the shape and number of holes, and this has been driven by advances in simulation tools. We no longer have to make as many prototypes or do as many tests on the dyno."

Looking to the future, Cornolti points to the big changes ahead in F1. "There has been some talk about incorporating energy recovery and regenerative braking, and this will be an interesting challenge. But it is too early to imagine how the system will work."

Brembo also works extensively in rallying. Ford, Mitsubishi, and various privateer WRC cars use Brembo systems. The stability of regulations in rallying mean that ongoing development every season is not such an issue. Although durability is obviously key, weight is also a problem – a compromise is always being sought. Cornolti says: "Like Formula 1, we are carefully developing the ventilation of the discs. We are also examining the cast iron disc material to see what improvements can be made. Often drivers influence the final choice based on their personal preferences."

NASCAR, meanwhile, presents a different challenge again. Says Cornolti, whose firm supplied 65% of last season's teams: "We use five kinds of brakes for the five different brake specifications. We have found that what is good for one series may not work in another. The Superspeedways of Daytona or Talladega require brakes that slow the cars for the pit stop. The teams don't want any brake drag. In races like Martinsville though, it's another story because it is a very small circuit with heavy braking every 10 seconds. Because the cars weigh over 1,600kg, the brake systems suffer a lot and it is vital to have a very good disc shape to dissipate the heat."

Brembo has a dyno that simulates everything that happens on every track, so a race like Martinsville can be run many times in the lab. After each run, the braking system is dismantled, and pad and disc wear examined. "Design is more important than materials in NASCAR," concludes Cornolti. "We will see new designs soon."

Pad up

Organic pad SEM shows the complex mix of ceramic, metallic and carbon-based fibers and particles in a typical brake pad formulation

"The 'organic' pads that work against cast-iron (auto) and stainless steel (moto) discs are usually bound together by a phenolic resin," says Edward Little, research manager for Federal-Mogul's racing and motorcycles division. "The substitution of phenolic resin by more thermally stable ceramic binders is already evident in some racing pads, resulting in more fade-resistant materials. Sintered material based on less melt-prone nickel and iron, rather than copper, may allow the sintered pads used in motorcycles, which are virtually fadeless but lack feel, to bridge the gap to auto racing if the heat transfer issues can be resolved. And if carbon-carbon manufacturers can find a way to produce a lower-cost material, we can probably expect to see technology trickle-down."

Life's a drag

RICHARDHEEPS.CO.UK

Retro-Rocket deploys the 'chute, Bakersfield 2003

Perhaps the most extreme form of braking in motorsport can be found in dragsters. Although the systems are relatively simple, the g-forces generated can be extraordinary. Former FIA European Top Fuel champion Andy Carter, proprietor and driver of Carter Motorsports explains: "My Top Fueler uses magnesium four-pot calipers operating on 292mm carbon-fiber discs at the back. There is no brake pedal; the system is operated by a hand lever in the cockpit. It's a very simple system with a small master cylinder feeding a line that splits over the axle."

There are no brakes on the front end, but wheeled braking is not the most important thing for these 6,500bhp monsters. This system is only really for staging, to stop the vehicle surging down the track after the burn out to warm the tires.

Carter continues, "The main braking on the dragster is from 3.6m (12ft) parachutes. When you get over the finish line, you pull the lever and release the cable to let the parachute out. I'll be traveling at over 480km/h (300mph) and I'll pull -7g as the car slows down. The chutes cut the speed by 160km/h (100mph) in under a second, so I can feel it...." To brace for this, Carter is tightly strapped in "by the strongest bloke in the crew".

Should an emergency situation occur half-way down the strip, there is little scope for controlled braking. The only option is to release the parachutes and, says Carter, "hope for the best".