BRAKE WITH TRADITION

More than 125 years after Ferodo's first experiments with composite friction materials, the company remains at the cutting edge of braking technology. By **Chris Pickering**

BACK in the pioneering days of the motor car, the problem of how to make these new-fangled contraptions go was inevitably followed by another question: how to make them stop?

Horse-drawn carriages already had rudimentary braking systems that pressed a block of material – usually rope soaked in tar – onto the solid surface of the wheel. As speeds rose, this approach began to prove hopelessly inadequate.

Various other systems were put forward, but most of these focused on the mechanics of how the braking pressure was applied. In 1897, a Yorkshireman named Herbert Frood decided to take a different approach. He focused on the friction surface itself, initially experimenting with a mixture of horsehair and bitumen, but soon switching to woven cotton impregnated with natural resin.

Frood was still working with horse-drawn vehicles at the time, but his resin-bound braking material was about to take off in the new world of motoring. Here, the use of rubber tyres had forced manufacturers to abandon rim brakes. In 1902, Louis Renault patented the drum brake, which quickly became the default option for the rapidly expanding number of car manufacturers. The same year, Frederick Lanchester took out his own patent for the first disc brake.

In the meantime, Frood had set up shop on the outskirts of Manchester, before moving to Chapel-en-le-Frith in Derbyshire in 1902. Two years later, he would name his company, taking an anagram of his surname and adding an 'E' as a nod to his wife, Elizabeth. The Ferodo trademark was born.

Frood's resin-bound material couldn't have come at a better time. He began manufacturing linings for drum brakes in 1902, and he's credited with inventing the modern brake pad. Lanchester's own experiments with copper linings and iron discs had resulted in an ear-splitting screech as the two metals made contact. Frood's composite materials solved this issue, although the disc brake wouldn't reach mainstream automotive use for another half a century. When it did, in 1956 with the Triumph TR3, it was Ferodo that made the first disc brake pads for road car use.

The early days

More than 125 years after Frood's first experiments with composite friction materials, Ferodo remains at the cutting edge of braking technology. The company now has more than 330 grands prix wins to its name, not to mention land speed records, Le Mans victories and a dominant presence in motorcycle racing.

One of the first major milestones on the racing side came in 1930 with the introduction of Ferodo's MZ linings. This quickly became the material of choice for manufacturers such as Alfa Romeo, which was sweeping all before it in grand prix racing at the time.

After the war, the next big breakthrough was the DS11 material. Originally intended for heavy-duty trucks and industrial applications, it was to become a game-changer in the world of motor racing. The material's exceptional fade resistance and

high temperature tolerance meant that the discs could be made smaller and the amount of cooling could be reduced. This meant that the cars weren't just better under braking; they had less unsprung mass, which improved handling, and lower aerodynamic drag, which improved straight-line speed.

DS11 was used in all types of racing, but its record in Formula 1 was particularly impressive. Between 1961 and 1981, all bar two grands prix were won by cars using Ferodo's seemingly invincible material.

But the company's dominance was about to come to an abrupt end. The early 1980s saw carbon-carbon brakes come of age in Formula 1. The technology behind these was – and still is – owned by a handful of aerospace companies. As with most motorsport pad materials of that era, DS11 also relied heavily on asbestos, which was about to be phased out. This meant its days were numbered in other series too.

Reborn

Ferodo's racing activities took a back seat for the next decade and a half. On the road car side, the original site in Derbyshire remains active to this day, with other Ferodo production sites spread around the ▶

BELOW Ferodo's seemingly invincible material won all but two grands prix between 1961 and 1981


LIFE CAPITAL GROUP
GRAN TURISMO
THE REAL DRIVING SIMULATOR
24
Carlisle
COVENTRY
R8 LMS
FERODO
H&R
RIEDEL
MICHELIN
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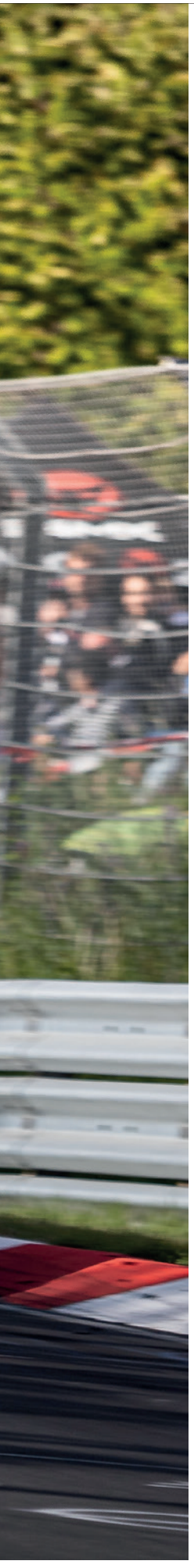


RIGHT Ferodo is racing on two wheels as well as four, as technical partner of Pata Yamaha Prometeon in WorldSBK

LEFT One important outcome of this winter's testing is the development of a new compound, TL163, specifically engineered for the rear axle of GT cars. It has a friction level and torque shape that make it compatible with ABS and wear characteristics that will make it a key player during the 2023 season

world. The motorsport division, Ferodo Racing, was revived and transferred to Mondovi, in northern Italy, in the mid-1990s.

Since then, Ferodo Racing has been run by Sergio Bonfanti, while technical manager Edward Little was drafted in from the UK to lead the R&D operation.

"We wanted to drag ourselves back to the forefront of motorsport," recalls Little. "At the time, the leading company in the field was one that had taken a material originally developed for mining vehicles and added a lot of abrasives to bring the friction levels up. It was not dissimilar, in a way, to what Ferodo had done with the DS11, and it effectively defined the modern racing friction material outside of Formula 1."

Ferodo developed its own material along a similar concept, known as DS3000. In use to this day, it has proven successful in a wide range of applications from touring cars to rallying, with a reputation for a strong initial bite and good modulation.

"I think a large part of the success of DS3000 comes down to the fact that it's a very capable all-rounder," comments Little.

Brake pad formulation is a science, but it's not an exact science, he points out: "There can be anything from 10 to 30 components in the material, ranging from fairly obvious ones – like carbons, graphites and ceramics – to some fairly exotic stuff. Friction dust, for example, is cashew nut oil, which is cured and ground up, and it has a particular effect because of its surface area. On top of that, there is a vast number of interactions between those components. So maybe 75 per cent of it is science and 25 per cent is a mixture of cookery and black magic. There is a degree of luck involved too, and I think with DS3000 we got it right for the requirements at the time."

While there might be a degree of sorcery that separates the good from the great, the majority of the work in brake formulation comes down to methodical testing, Little explains: "We had a very good structure for developing the materials. For instance, we had techniques for analysing which was the strongest iron powder that we could put in; which was the most heat-resistant graphite that we could use, and so on. From that point onwards, a lot of it comes down to statistics. If you have enough time to test 100 brake pad formulations rather than 50, you've got twice the chance to find something that really stands out." ▶

BELOW With sales of eBikes rising more than 500% over the past nine years, Ferodo Racing has launched a specialized range of brake pads, discs and brake fluid for both conventional and electric bikes

Ceramic resins

For over a century, phenolic resins, similar to those used by Frood, remained the base material of choice for most braking applications. The mid-2000s saw the introduction of ceramic resins. Once again, this technology had emerged in other industries before being brought into motorsport, where the ceramic materials' excellent wear resistance and broad range of operating temperatures were significant benefits. Ferodo harnessed this technology for a new generation of pad materials, starting with DS1.11, which was later joined by DS Uno. Both have found success across a broad range of disciplines, including touring cars, one-make championships and single-eaters, with DS Uno also doing well in rallying.

GT racing

While DS1.11 and DS Uno had brought Ferodo back to the forefront in tin-tops and the junior formulae, the company was keen to tap into the fast-growing GT racing market. To do this, Little and his colleagues on the racing side in Italy once again collaborated with the road car engineers back in the UK. Together, they went back to basics, stripping the brake pad formulation right down and building it up again from first principles.

"This required quite a long-term approach, because we weren't just tweaking the materials, we were stripping it back and building it up, and evaluating new materials along the way," he notes. "As well as developing the new formulation, it gave us a huge library of materials and properties that we're still working with."

This project led to the launch of DS3.12 in 2019, which is Ferodo's halo product, covering the upper echelons of GT racing, stock cars and other heavy-duty motorsport applications. However, it's also started to establish a broader family of materials developed around the same work.

> *"Originally intended for heavy-duty trucks and industrial applications, the DS.11 material was to become a game-changer in the world of motor racing"*

"Subsequently, the development work we did for DS3.12 has come to help us in other applications. We came to realise, for example, that the way that the ABS is engaged and released can be just as important as the outright friction level in some GT classes and on some circuits," comments Little. "We've had that feedback through our relationship with the teams, and we realised that we had materials that seemed to offer exactly the sort of characteristics they needed when we had dyno tested them during the development process. So that means we sometimes have ready- ▶

ABOVE The DS.11 friction material was conceived for industrial applications but went on to dominate in F1, winning 265 times in 267 races

BELOW The launch of DS3.12, Ferodo's halo product, won it a foothold in the upper echelons of GT racing. The research involved is also helping establish a broader family of materials that have proved popular in touring cars, one-make championships and single-seaters

made solutions to problems like that, which enables us to react very quickly."

Fundamentally, the development process hasn't changed a great deal, he points out. With so many variations within the pad material itself, the engineers try to minimise the external variability by picking a single disc and caliper setup to use as a baseline for the initial testing.

The metallurgy of brake discs has become somewhat more complex over time. Most are still made from grey cast iron, which uses flaked graphite to improve the stiffness, thermal conductivity and heat capacity of the iron. Over the last 30 years or so, a growing number of brake disc manufacturers have started offering spheroidal cast iron, which is sometimes claimed to offer improved wear resistance. The impact on the pad material, however, is negligible, so it can be neglected during the initial development.

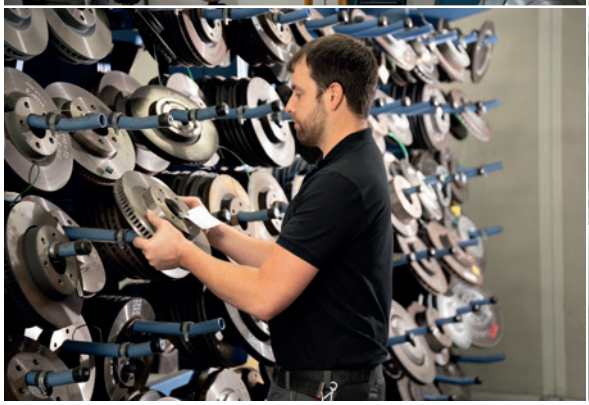
Once track testing commences, the formulation can be refined to suit small differences in pad metallurgy and brake system design. Still, the variables are relatively small: most high-end GT cars, we're told, use one of two brake systems on the front axle. Generally, it's the layout of the cars themselves that poses a greater significance, with a wide range of vehicle weights found in GT racing, allied to a mixture of front, mid and rear-engined configurations.

Counter-intuitive thinking

The most significant change in GT car braking systems in recent years has been the adoption of ABS.

"The arrival of ABS was a big step," comments Ferodo Racing's general manager Sergio Bonfanti. "It forced us to look at our dyno results in a different way before putting the friction material on a racecar. We have to look far more carefully at things like how the friction level changes throughout the braking event. The friction coefficient of a traditional brake pad tends to rise as the car slows down, so that's something we've had to iron out."

This constitutes a fundamental rethink of the brake pad formulation. In the past, the friction material had three key tasks: it needed to provide very high friction to slow the car; wear resistance to provide sufficient durability; and fade resistance to ensure consistent performance at high ▶



ABOVE Ferodo harnessed its expertise with ceramic resins to develop a new generation of pad materials such as DS1.11 and DS Uno (pictured). Both found success across a broad range of disciplines, with DS Uno also doing well in rallying

LEFT The science and the facilities (Ferodo's dyno hall, prototype shop and vehicle testing workshop are seen here) continuously evolve, but there remains one constant: 125 years of innovation

Jaguar

temperatures. The advent of ABS means that outright friction levels are actually less critical than they were before. Instead, it's about ensuring that the ABS engages and disengages smoothly.

ABS has also changed the balance between the front and rear braking systems, Little points out: "In the past, it was generally the front brake pads that did most of the work. The rears would just need to be a capable material that could prevent fade and offer high-ish friction. Now, we're developing materials for the rear pads that are deliberately very low in friction. They have a very flat friction profile, so the relationship between the pressure you put into the pedal and the torque that you get from the brake is completely linear."

> *"Friction dust is cashew nut oil, which is cured and ground up, and has a particular effect because of its surface area"*

Even a few years ago this approach would have seemed highly counter-intuitive, he admits: "Until recently, if you'd suggested this to a motorsport brake formulator they'd have thought you were mad. But that's what the market requires these days to get the right balance, because lockup is so prevalent on the rear wheels. That means that rear wheel performance is almost more critical than the front now – or at least there's now a strong synergistic relationship between the two. It's changed the way we think about the rear brake completely."

The trend towards these so-called digressive brake pads has prompted Ferodo to return to the dyno testing of the 150-or-so materials that it catalogued in the lead up to the launch of DS3.12. Ironically, it's often materials that were towards the bottom of the pile originally that are now coming into their own with the new requirements.

To put things into context, a front pad would perhaps have a friction coefficient of around 0.5, whereas the rears would now be something like 0.3. Relatively speaking, this translates to more lubricants in the pad formulation and less abrasives. This front-to-rear friction split also plays an important role in loading the rear tyres and keeping them up to temperature, which benefits traction and cornering as well.

"The most difficult part of the braking is the combined phase, where you're still braking but you're starting to turn in," comments Bonfanti. "You can gain several tenths each time by really optimising the braking. Even at somewhere like Monza you're potentially talking about a second a lap just from the braking. So we're trying to avoid any interference from the ABS when you first get onto the brakes and when you release them going into the turn."

The car is also effectively coasting while the ABS is engaged, he points out. Almost by definition this is lost time – neither shedding excess speed nor driving out of the corner – and it also gives the driver less control.

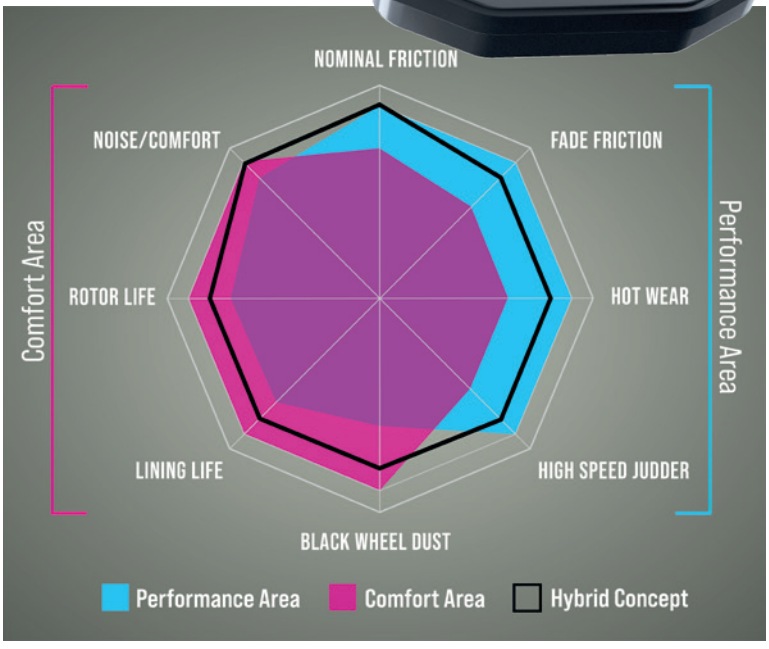
"While the ABS is active, you're not driving the car – at least as far as the brake input is concerned – the car is driving you," Bonfanti observes.

The future

While ABS optimisation might be the biggest talking point in GT racing at the moment, there's an even greater challenge on the horizon. Hybridisation is largely the preserve of top-tier prototype and single-seater categories at the moment, but the arrival

ABOVE Electrification is increasingly a factor. Ferodo provided the brake pads for Formula E's Jaguar I-PACE eTrophy support series

BELOW Leveraging its comprehensive material science expertise, Ferodo's OE business has introduced advanced copper-free hybrid friction material composites that simultaneously serve braking performance and comfort requirements in both ICEs and EVs



LEFT Years of painstaking work in the laboratory underpin the breakthroughs made on road and track

of road-going hybrid supercars like the McLaren Artura, the Ferrari 296 GTB and the Honda NSX – all of which have racing variants currently running IC-only powertrains – begs the question of whether we might see electrification start to play a bigger role on the track.

"We need to understand how the electrification is going ahead, because, for sure, that is driving a lot of development work on the discs," comments Bonfanti. "Cast iron has been very stable for the last 25 to 30 years, but we're now seeing a lot of pressure to take away weight in other areas of the car as electrification brings additional mass to the powertrain. Any changes to the discs as a result of that will surely prompt a change to the pad materials as well. That's something we've already seen on road cars, but not yet in the racing industry."

Clearly, the role of the friction material would change too. On the road car side, Little points out, peak friction levels have become less critical, as brake-by-wire systems have prioritised regenerative braking. Instead, wear resistance and noise levels have come to the fore. Even challenges such as stiction corrosion are starting to emerge as road cars use their mechanical braking systems less.

Currently, there's a degree of divergence between increasingly electrified road cars and predominantly IC-only competition cars. However, that might not always remain the case, and there are already exceptions. Ferodo provided the brake pads for Formula E's Jaguar I-PACE eTrophy support series, for instance, and it's understood that the low noise levels were part of the reason that the material was chosen. After all, if you're looking to showcase the refinement of your new EV, you don't want each car squealing as it rolls down the pitlane.

Environmental concerns are also likely to play an increasing role in the motorsport industry, from brake dust emissions to manufacturing impact. In the United States, copper, which can be toxic if it accumulates in the environment, will effectively be banned from road car brake pads as of 2025. Currently, the proposed ban doesn't apply to motorsport products, but it's something that Ferodo is keeping an eye on as it seeks to reduce its impact. Elsewhere, the brand has reduced the use of plastics in its packaging by 98 per cent, and the majority of the energy used in the factory is now taken from solar panels on the roof.

It's all a far cry from Frood's Patent Brake Blocks. But in other respects, the methodology and even some of the materials used in the formulation, haven't changed that much. It does make you wonder what the next 125 years might bring. RT

RIGHT Environmental concerns will inevitably influence motorsport, as they have the automotive business. Ferodo has been supplying low- and zero-copper friction products since 2012. Its formulations were developed using a tribological fingerprinting process to identify alternative materials that can provide the same stopping performance, noise, vibration and harshness (NVH) characteristics and durability performance as traditional copper brake pads