TINY TECHNOLOGY: BIG BREAKTHROUGH

Despite its extra expense, nanotechnology is poised to make major inroads into motorsport lubricants. **John Coxon** investigates some rave reviews

THE CUT and thrust of touring car racing isn't the first place you would look for new and innovative technologies. But within the paint-swapping action of the tin-top boys a quiet revolution is currently taking place. And if early results are anything to go by, these latest developments could lead to a major shift in technology for motorsport lubes and, in the longer term, perhaps even automotive oils in general.

Much of this early work is being done in the specialised world of gearbox lubricants. But given impressive results so far in the British Touring Car Championship, already plans are being developed to transfer the technology onto engine developments. As you read this, the first of the Millers nanotechnology competition engine oils will be pounding around the British circuits.

A staunch advocate of solid lubricants in some types of transmission oils since the advent of "Black Moly" in earlier formulations, Martyn Mann, technical director at Millers Oils in West Yorkshire, was all too aware of the weaknesses and problems associated with conventional lubricants. "Conventional lubricants are traditionally sensitive to heat and their ability to take heavy or shock loading in gearboxes, particularly as temperatures increase, can be of major concern. This heat not only reduces the viscosity of the oil but can have the secondary effect of acting as an initiator for oxidation," he claims. "In engines as well, boundary and mixed lubrication regimes are typically observed in the piston ring at top and bottom dead centre as well as in the valve train and on gear flanks. While the 'wedge' of lubricant separates components under hydrodynamic lubrication, in those zones typified by boundary and mixed regimes the presence of another 'entity' is necessary to prevent excessive wear."

EXTREME PRESSURE ADDITIVES

In engines this other "entity" is the anti-wear component introduced to 'cling' to the metal parts when the wedge of oil disappears. Until recently it has been the province of ZDDP additives. In gearboxes, particularly those characterised as API GL4 and GL5, the use of these EP or 'Extreme Pressure' additives is not always desirable and so other less active sulphur-phosphorus compounds are more generally used.

But conventional lubricants also have other weaknesses. For instance, they do not provide suitable solutions to high load ▸

LEFT Exceptional transmission lube performance is spearheading the introduction of nanotechnology into the engine crankcase lube in the BTCC

RIGHT The science coming to a race championship near you ! Fullerenes act like ball bearings to keep surfaces apart under high load

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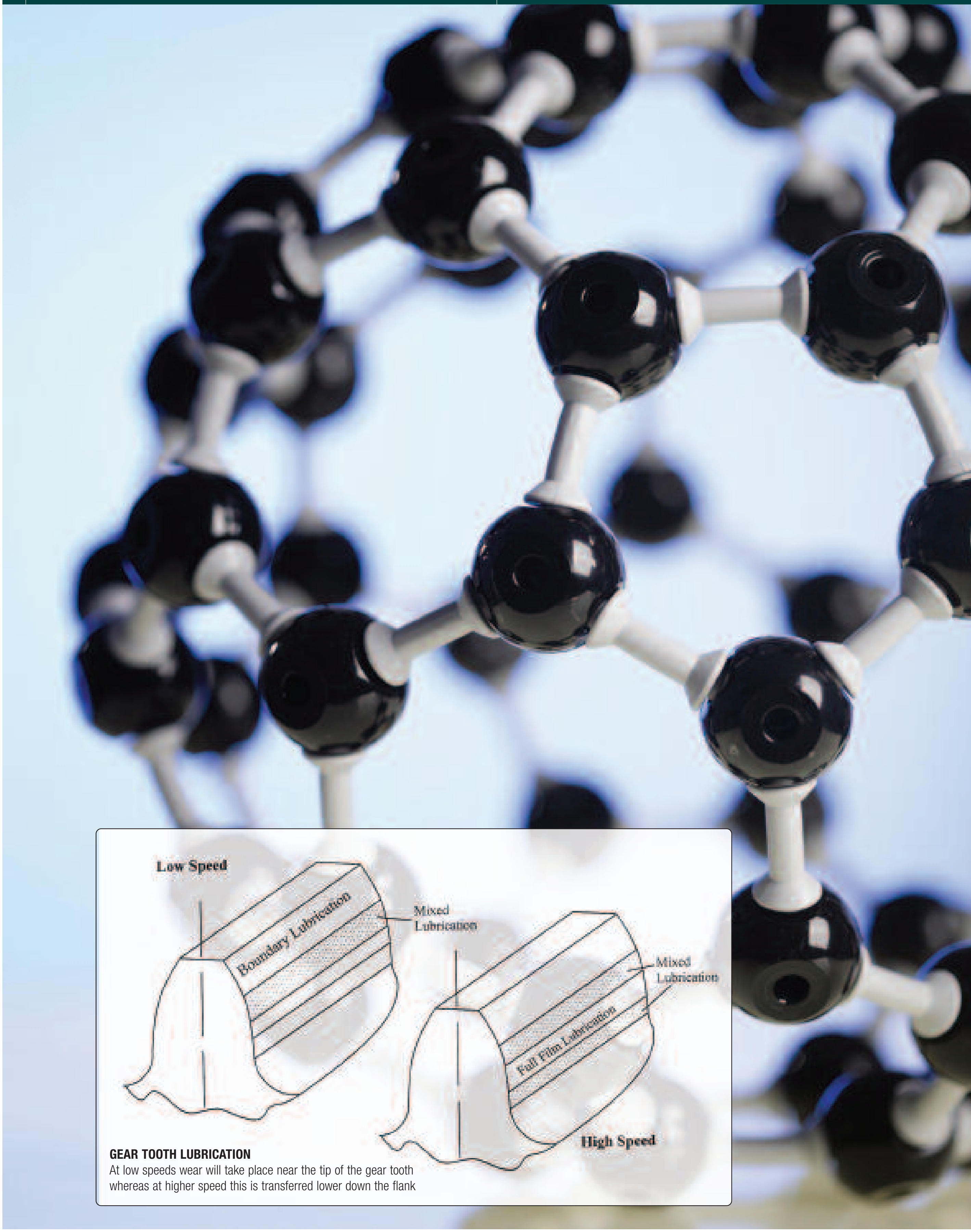
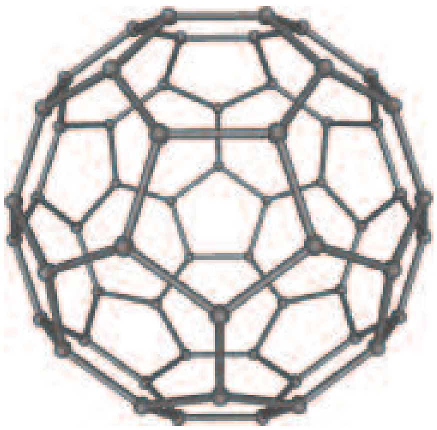


GEAR TOOTH LUBRICATION
At low speeds wear will take place near the tip of the gear tooth whereas at higher speed this is transferred lower down the flank



ABOVE This football-shaped fullerene is made entirely from carbon but now scientists believe that fullerenes can be made from many organic or inorganic substrates

cycling conditions when cavities formed on or just underneath the metal surface can cause fatigue wear. Neither do they afford sufficient protection under low amplitude oscillating conditions when the lubricant can be expelled from the friction zone. A perfect example of the latter is the meshing between two gears in a gearbox where the very high loads on the gears can have the effect of squeezing out the oil. If the movement is slow, the oil has sufficient time to flow away and so 'thicker', more viscous base oils tend to be used. At high meshing speeds, full film lubrication will take place on the gear flanks with mixed conditions towards the tip of the gears. At slow speeds the tips of the gears will experience wear-inducing boundary layer conditions unless some form of anti-wear or EP additive is used.

PHYSICAL BARRIER

Research at Millers Oils, which is associated with no fewer than six teams in this season's BTCC, suggested that solid lubricants could be the solution to these limitations. "To start off with, they are more resistant to high temperatures and pressure and form a physical barrier between the mating surfaces themselves," says Mann. "This covering capacity is very high and effectively fills in the surface asperities and any surface cracks, presenting a much smoother external surface to the lubricant. By evening out the load across the surface, solid lubricants can therefore interfere with the mechanisms producing surface pitting, galling or fretting as well as preventing small fissures from propagating in the surface. On the formulation side, solid lubricants can be readily dispersed into the oil and incorporated into the finished lubricant as either a complementary additive or, if necessary, as a substitute for any conventional anti-wear/extreme pressure compounds."

However, when you consider solid lubricants, thoughts of graphite and molybdenum disulphide immediately spring to mind. These dry powder lubricants are perhaps more usually found in speciality greases and some engine oils, but as well as settling inside engine oil filters, graphite has been linked to corrosion of some aluminium engine parts in the presence of water; as such, it is not really suitable for engine oils. On the other hand, molybdenum disulphide has been successfully used in Millers' high shock transmission oils as late as last year (in the form of Black Moly). But issues associated with its manufacture – its intense blackness – made it unpopular in the blending plant. So when the opportunity arose to redesign Millers' complete range of competition gearbox lubes, a new and exciting concept was adopted: nanotechnology and inorganic fullerenes, or IF to those in the know.

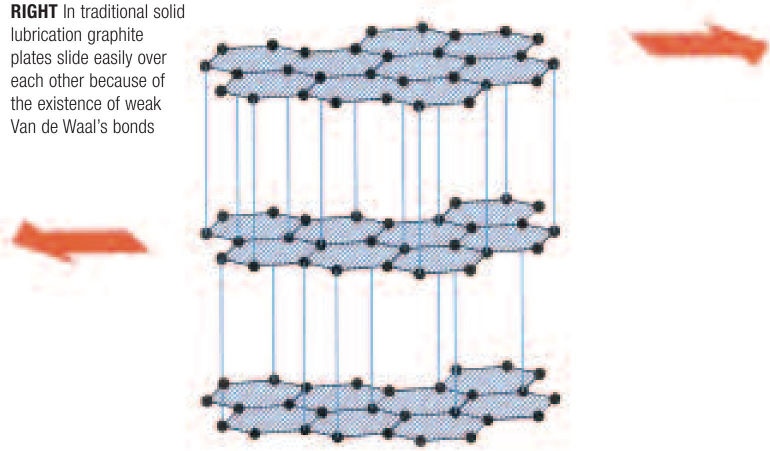
> "A new and exciting concept was adopted: nanotechnology and inorganic fullerenes"

Discovered in 1985 by Messrs Curl, Kroto and Smalley at the University of Sussex and Rice University, fullerenes are a family of carbon allotropes – molecules composed entirely of carbon in the form of hollow spheres, ellipsoids, tubes or planes. When spherical in shape, they can often be referred to as 'Buckyballs' after Richard Buckminster Fuller whose particular type of shell or lattice structure (geodesic dome) it resembles.

Fullerenes are similar in structure to graphite, which is composed of stacked sheets of linked hexagonal rings, but will also contain a mixture of pentagonal or heptagonal rings that would prevent a sheet from being planar. Interestingly, the shape of the association football is based on the C_{60} fullerene, more precisely referred to as the Buckminsterfullerene.

So significant was the discovery in the scientific world, that in 1996 the trio were awarded the Nobel Prize for Chemistry. In 1992, however, it was realised that graphite was not the only element in the periodic table that could form fullerenes or nanotubes. In fact, any compound exhibiting a layered structure is highly likely to display this property. Thus molybdenum disulphide or similar lattice structures could all form closed polyhedra or nanotubes of some type or another and, when in a multi-layer nested form, could indeed be the most stable of all. ▸

RIGHT In traditional solid lubrication graphite plates slide easily over each other because of the existence of weak Van de Waal's bonds



These fullerenes behave totally differently as a solid lubricant to the more conventional materials. Graphite, for instance, relies on the different layers of the lattice sliding over each other to reduce the friction. Fullerenes, however, act more like ball bearings between two surfaces and under high load or shock can distort and unravel to retain separation.

While conventional solid lubes work at the molecular level, fullerenes work at the nano level, which is considerably bigger. Sized somewhere around 60 to 100 nanometres (10^{-9} metres), these multi-layered spherical and nested structures look very much like onions under the microscope. The covalent bonds link the metal and sulphide atoms together within the same layer, which can wrap around on itself to form a tube or sphere. Between the layers, much weaker Van-der-Waal interactions exist which assist the layers to move relative to each other, changing the shape of the structure depending on the loads upon it. Because of this, IFs are far more resistant to the physical constraints and don't shear as easily as the corresponding lamellar products.

If that were not enough, the lack of 'free' sulphide atoms makes them much more chemically unreactive, perhaps even inert, and therefore highly resistant to oxidation. While important in gear oils, this is even more so in crankcase lubricants.

In other forms of anti-wear, the additives are generally drawn to the surfaces to be protected by polar attraction. Although having no overall electrical charge, either positive or negative, the molecule has an electrical dipole which gives it an affinity for metallic surfaces. This can often compete with other surface-active additives, for instance the detergents, and is why it is ▶

GEARBOX OILS

TRANSMISSION oils, although similar to engine crankshaft oils in make-up, have totally different demands. Like engine oils they need excellent viscosity-temperature characteristics but it is important to note that the viscosity grades of gearbox oils are very different to those of engine crankcase lubricants.

Not too viscous at low temperature, the viscosity needs to be adequate at high temperature to protect the highly loaded gears. The oil is therefore said to need a high viscosity index (VI). In engine oils viscosity index can be increased by the addition of modifiers, which cause the oil to thicken as the temperature increases. This means that 'thinner' oils can be used to combat the low temperature viscosity and are quite normal in engine crankcase oil.

However, unlike engine oils, gear oils undergo a substantial amount of shearing in operation and so oils need to be highly shear-stable. Any VM long chain polymers added to the mix would therefore get chopped by the incessant action of the gears and would rapidly become ineffective such that the lubricant would become too thin after a short while. For this reason the best gearbox oils are high quality, high VI oils.

In addition to all the other additives required (dispersants/detergents, anti-corrosion additives, anti-oxidants, anti-foam etc), wear protection will be needed according to the type of gears, speed and loadings experienced. Thus different grades and formulations may be specified depending upon the running temperature of the gearbox and the type of gears used.

BELOW TH Motorsport reports a much reduced spend on replacement gearbox parts after using the new oil in its Honda Integra unwise to add other compounds to engine or gearbox oils when the surface activity of one component may overpower that of another to the detriment of the total. As EP anti-wear components, fullerenes are not surface active at all and so can be used alongside other anti-wear or surface-active components should that be necessary. This therefore reduces the cost and complexity of product testing in the early stages.

You may have the most exciting and innovative product around but, as anyone who deals with any form of chemicals in the workplace will know, it is simply a non-starter unless it passes all manner of health and safety regulations. Since lubricants consist of a cocktail of any number of individual chemicals, each one having to be individually approved, the matter is far from straightforward. Fortunately, the unreactive characteristic of the structure is that same characteristic that makes the fullerenes both non-toxic and dermatologically safe. The product therefore passes all current health and safety standards.

> "Fullerenes can distort and unravel under high load or shock to retain separation"

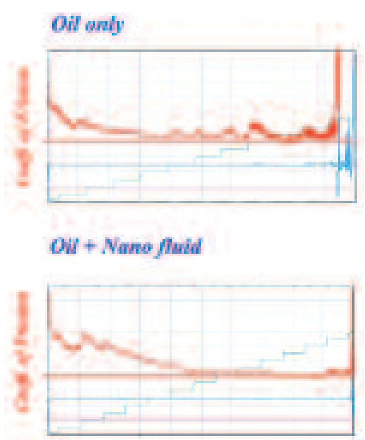
The downside, almost inevitably, is the cost. Bought in from a separate supplier and carefully blended into the revised formulations of the new range of oils, it is currently only financially viable with specialised products like those of the Millers range of competition gearbox oils. It is a case of 'you only get what you pay for,' if ever there was one.

Among the teams in the BTCC using the oil, there is nothing but enthusiasm for the product. According to Trevor Humphrey of TH Motorsport, which runs John George in a Honda Integra, "It seems to cope with the heat much better than any other oil and retains its viscosity far longer. The oil seems to stick to the gears and dog rings much better; approaching the halfway point in the season, we had spent about only half of what we spent last year on replacement gearbox parts."

Sequential gearboxes take some quite brutal loads and the extra EP protection during the shock loading seems to be visibly noticeable. Humphrey also mentions that the oil seems to be better at picking up any fragments of metal and depositing them into the filter. No doubt this is a benefit of the reduced surface activity of the anti-wear system allowing the detergent/dispersant package to be more effective. For teams paying their own bills, such benefits would suggest that this is becoming a 'must-have' technology.

Indeed, the response to the performance of the oil is such that plans are being drawn up much earlier than originally anticipated to introduce inorganic fullerene technology into the engine crankcase. To date the new-for-2009 Team AON has adopted a conservative strategy to its crankcase oils, using a 5W-40 competition oil classed as 'full synthetic' with a surface-active triple ester formulation. This is as you might expect for a team needing absolute reliability as it progressively extracts more power from the two-litre engine. Based on its experience with the IF oil in its gearboxes, though, the team is now looking to transfer this nanotechnology into the engine oil.

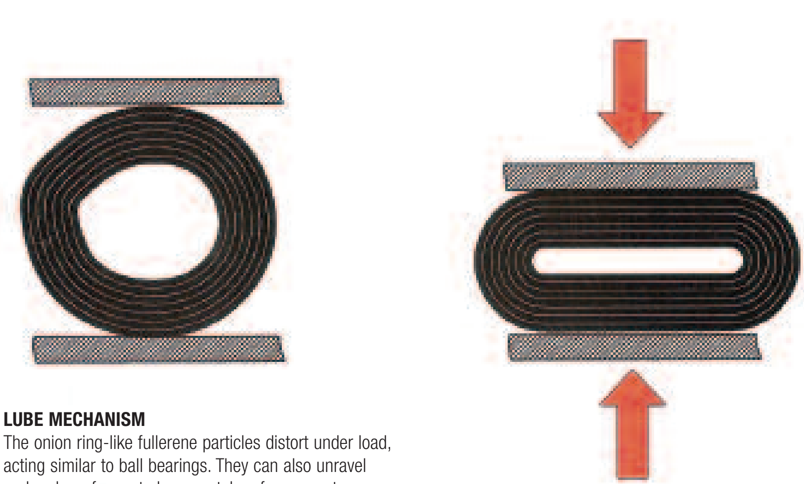
SYNTHETIC OIL Ball on plate rig test
The presence of nanotechnology reduces friction slightly but gives a much 'cleaner' signal, indicating the reduced amount of wear taking place



ENGINE OIL TRIALS

"We shall do some development work on the dyno and examine the components before committing ourselves," says Dick Langford of Team AON engine supplier Langford Performance Engineering – which, incidentally has already run a 0W-20 formulation. "The technology has been very successful in the gearbox and we are looking to transfer some of its advantages into the engine oil."

Taking the conservative route, the engine is to be dyno-tested on a 5W-40 nanotech oil similar to that currently used in order to provide benchmarking data. Assuming it is successful, the viscosity will then be reduced in the chase for reduced friction and extra engine performance. RT



LUBE MECHANISM
The onion ring-like fullerene particles distort under load, acting similar to ball bearings. They can also unravel under shear forces to keep metal surfaces apart