FRATERNAL TWINS

FORMULA 1 TECHNOLOGY ARRIVES AT THE SHOWROOM.

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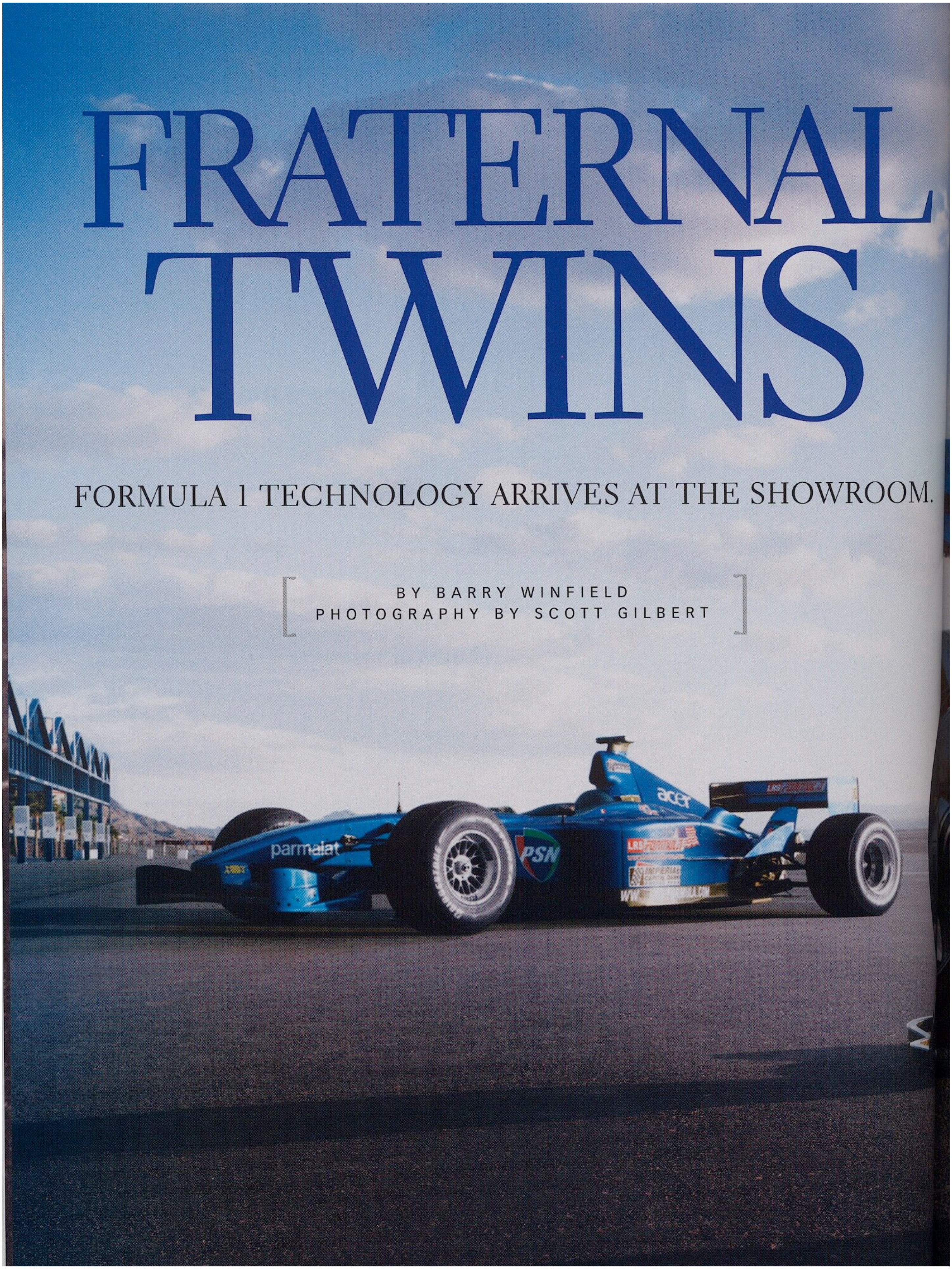
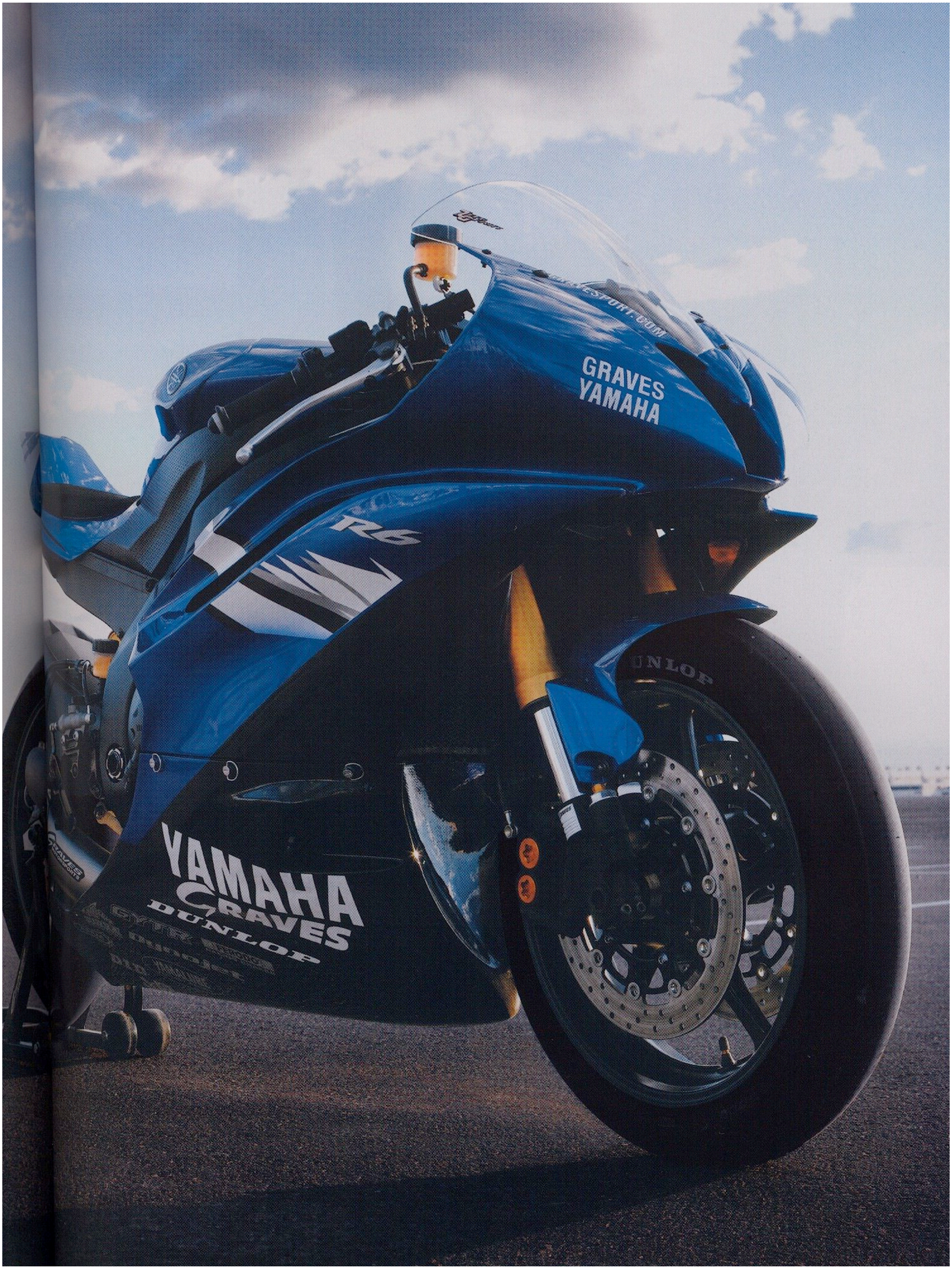
PHOTOGRAPHY BY SCOTT GILBERT]

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In the stillness of a high desert afternoon, we can hear the 2006 Yamaha YZF-R6 clearly as it makes a test run toward us. Considering the bike is still at some distance, the high-pitched wail cuts through the air with amazing clarity, and the gearshifts come in quick succession as the 599cc engine rips through the top end of its rev range in each gear. Close-ratio transmissions make that possible, and they are invariably fitted to high-revving engines, where the power band is comparatively narrow and crowded into the top end of the engine's usable rev range. In this way all ultra-high-performance engines are related, because the principles observed in the design and development of high-output engines are essentially the same everywhere.

Because all engines have numerically equal torque and power values at 5,252 rpm, by definition, the only way to extend the horsepower of a particular engine is to raise its rate of work by increasing the speed at which it operates. Loosely speaking, torque multiplied by revs (divided by 5,252) equals horsepower. That's why, when we saw early versions of Yamaha's R6 at the big motorcycle shows that preview each year's new models, the big shock was a tachometer with a 17,500 rpm redline. Was it possible, we wondered, for Yamaha to have produced a production engine for a street-legal motorcycle with rotational speeds in the rocket-science realm of Formula 1?

It didn't take long for the answer. No, Yamaha had exploited a fairly typical nine-percent tachometer over-read inaccuracy for its shock value in this innovation-driven motorcycle market segment. Aftermarket tuners, working with sophisticated electronic dynamometers, soon discovered that the bike's ignition-control module limits engine speed on the R6 to about 16,000 rpm. That's pretty high, but it isn't much higher than what other 600cc supersport manufacturers currently use. Suzuki's GSX-R600, for one, wears an honest 16,000-rpm tachometer redline.

Still, the Yamaha engine makes extraordinary power for such a modest displacement, generating 131-horsepower at 14,500 rpm, according to Yamaha's publicity materials. Moreover, dyno tests show that it continues to make significant power well beyond the 14,500 rpm power peak. That calculates to a specific output of 220 hp per liter. Remember, it wasn't so long ago that 100-horsepower-per-liter was considered pretty good in a normally aspirated engine.

Currently in F/1, specific output beyond 300 hp/liter is the norm. This is accomplished with engines that are required to fulfill two weekends' of testing, qualifying and racing—no mean feat given the technological ragged edge on which these engines live, but still a far cry from the role expected of Yamaha's little 600. That engine must meet international emissions and noise regulations, start and run reliably every day without external starters and laptop supervision, meet stringent warranty requirements, and provide civilized drivability and good fuel consumption.

Admittedly, some of those challenges take a backseat on the Graves Motorsports Yamaha R6 seen on these pages. Despite competing in a Supersport formula heavily based on production machinery, with modifications severely limited in

Suspension performance is crucial to the success of the Graves Motorsports R6 on the race track. Data acquisition from the Öhlins.

scope and magnitude, the R6 is allowed less restrictive induction and exhaust flow, along with whatever fuel injection and ignition mapping changes the tuner considers helpful.

It's increasingly clear that today's 600cc sport motorcycles are developed with a view to racing in the AMA national series as well as in the FIM World Supersport championship. Much of the technology employed is the same as in any prototype racing engine. Straight-shot ports conduct the fuel/air charge directly into the cylinders. Four valves optimize gas flow into and out of the cylinders, and they're made as large as the bore size will allow. The cylinder head design is painstakingly shaped to promote fast and complete combustion, with a high compression ratio for optimal gas expansion rates. The engine geometry embraces a radically over-square design (where the stroke is short relative to the bore), and the pistons are lightweight units with minimal skirts and relatively thin, low-friction rings. Special vents between the crankcase compartments reduce pumping losses at high revs.

The R6 uses linerless cylinders with ceramic-composite coatings to keep block weight down, and it is exactly this kind of exotic technology that was pioneered by Formula 1 teams. For example, Mercedes F/1 engine suppliers Ilmor Engineering developed the use of beryllium-aluminum piston materials in the late '90s, but when this material was outlawed because of possible health hazards, the GP circus moved onto so-called metal-matrix composites deployed in

Computer science joins physics as lead players in the success of today's high-performance competition machines.

linerless cylinders in much the same way as on the R6. Other lightweight materials are exploited in both disciplines, with titanium and magnesium castings used wherever they can pare off a few ounces. The R6 uses a titanium exhaust system, while F/1 cars go for thin wall Inconel tubing. Advanced metallurgy is common to car and bike engine design, finding applications in low-friction bearing material as well as in low-weight casings and componentry.

As engine speeds rise, friction becomes a greater factor. Some internal losses quadruple as engine speeds double. At least a few motorcycle racing teams have discovered that ongoing development produced higher engine speeds, but the resultant increases in power have been eaten by increased friction. One answer has been to reduce bearing area to the very minimum, but that's a technique fraught with risk. Bearing failure ends your race, and it isn't good business on the consumer side either. Bearing life can be greatly extended with good design, and that's where the computer often comes to the rescue. Modern design and simulation software helps produce engines that are stiff and strong, resisting the bending and flexing that occur at very high operating speeds. Maintaining exact alignment is key to bearing life, and a close look at both F/1 and high-output motorcycle engines quickly reveals the lengths to which designers have gone to embrace maximum structural integrity. The castings are replete with webs and gussets, and crankshafts are mounted in heavily reinforced bearing ladders.

One aspect of F/1 technology not in use in motorcycle racing, but bandied about in respect to the new 800cc MotoGP formula is the use of pneumatic valve springs. The R6 and the F/1 car pictured here utilize lightweight titanium valves to minimize reciprocating mass, but steel is still the only practical material for valve springs in conventional engines. Because steel springs have a natural frequency that

"With 45 streams of data, we acquire a lot of technical information to interpret."

can be excited at certain operating speeds, they are prone to valve float—a condition that interrupts normal opening and closing functions.

Along with the Prost-Peugeot seen here, the American Racing Academy in Las Vegas runs Arrows and Benetton cars powered by Cosworth HB V8 engines—among the last F/1 engines to use steel valve springs. At the HB's rev ceiling of about 14,000 rpm, valve float was not much of a problem. But as engine speeds crept toward 17,000 rpm, F/1 engines needed something other than excitable valve springs. Renault is credited with being the first to develop a pneumatic valve-return system, debuting the device on the RVS-9 engine that propelled Nigel Mansell (1992) and Jacques Villeneuve (1997) to F/1 world championships. It's said that Jean Todt, director of racing management at Ferrari, brought technicians who were expert in the field of pneumatic valve control with him when he joined Ferrari, significantly advancing that company's knowledge of the art.

The 3.5-liter Peugeot V10 in this Prost car had pneumatic valve springs powered by compressed air stored in an accumulator. That technology was considered inappropriate on motorcycles until 2005, mainly due to packaging concerns, and because engine speeds weren't yet at the level where valve-float was a serious issue. In fact, Honda raced a five-cylinder 250 as far back as 1965—the RC148—that revved to 20,000 rpm with conventional poppet valves; so it can be done. But current MotoGP machinery is forced to employ super-high rev ceilings in order to stay competitive, and with the 800cc displacement demanded in 2007, we will see more teams fielding entries with pneumatic valves similar to the systems already tried by Aprilia in its "Cube" MotoGP bike (whose engine apparently had Cosworth input) as well as on Suzuki's current GSV-R.

Engine technology isn't the only arena in which Formula 1 and race motorcycles are similar. Both use sophisticated data acquisition systems to monitor and measure various aspects of the engine and suspension performance while the machines are running. In the case of Formula 1, the data is fed as real time wireless data to instruments in the pits, where the information can be reviewed on monitors in real time. Because the cars are in radio contact with the crew, this is pretty useful. A warning to a driver about an alarming technical trend appearing on the pit monitors can save an engine or even potentially avoid an accident.

Formula 1 used to have two-way telemetry, where running changes to some of the car's settings could be made on the fly, but that's no longer allowed. Motorcycle race crews, on the other hand, have to make do with downloaded data when the bike stops, but it's still an invaluable diagnostic tool. The Graves Motorsports chassis data acquisition guru, Chris Lessing, who plays a key role in the instrumentation of this Yamaha R6 and has also worked for Team Roberts MotoGP and the Dutch Ten Kate World Superbike team as well, says that information from sensors measuring suspension forces helps provide an accurate picture of what the machine is doing. "With approximately nine channels mathematically developed into around 45 streams of data, we acquire a lot of technical information to interpret," he says. Everything from the amount of suspension deflection, frequency of movement, wheel speeds, position, acceleration and so on relate directly to the setup the crew has to select from. The real skill is in the interpretation of the data, and that's why Graves Motorsports flies Lessing in from South Africa at regular intervals to consult with the team.

Team owner Chuck Graves says there is a simulation function in the analytical software that allows the team to assess the likely effect of whatever alterations they make to the suspension setup before they do it. But, he adds, "the emphasis in this line of analysis is very much on making the rider happy." Rider confidence is everything in motorcycle racing, so even if changes are likely to compromise the bike's performance according to the interpretation software and the data acquisition technician, it is still worth doing to satisfy the rider. Naturally, the engine has its own sensors and data logger to ensure that it, too, is operating at an optimal level and that information is then reviewed by Graves' engine specialist.

One area of research explored by both F/1 and sport motorcycle engineers is aerodynamics, but the application of their findings is probably more divergent than in any of the other technical areas under review. Motorcycles need to cut through the air with minimal drag, and to do so without any destabilizing aerodynamic effects, and that's pretty much the focus of the engineers' job. Obviously, enough air has to reach the cooling radiators and induction tract, but other than that, the bike should be as slippery as possible. Because motorcycles lean into curves, there is no possibility for the generation of aerodynamic downforce to assist in the amount of traction available. And it shows. Bikes racing around the banking at Daytona are spinning their rear wheels approximately ten-percent faster than the speed of the machines themselves. Bikes driving off slow corners frequently spin up the rear wheel as the power exceeds the amount of available traction.

That lack of traction is exactly what prompted F/1 designers over the years to add wings, underfloor tunnels and undertail diffusers to the cars that suck them down tight on the track, promoting efficient traction at the driving wheels and incredible traction in the corners. In an attempt to slow the cars for safety reasons, the underfloor tunnels have now been ruled out of existence, but much of the emphasis in F/1 chassis design is now trained on aerodynamic efficiency. As an example, between the recent MotoGP race and the similar Formula 1 race at Sepang in Malaysia, the F/1 lap times were a little over 30 seconds faster than their motorcycle counterparts. And the motorcycles have higher top speeds and accelerate in similar times. Think about that—the 25-percent time advantage for the car is clearly made up in the corners, an astounding testament to efficiency of aerodynamic downforce and four large tire contact patches on the tarmac. The cars actually carry so much wing surface that considerable drag occurs as a by product of maximizing downforce. It has now reached the point where a simple lift of the throttle produces about 1*g* of slowing, and that's about what a good production road car like a Corvette can manage at maximum braking power!

It is inevitable that available technology will continue to make its way from the track to the street. That the R6 has so much in common with motorsport's premier racing class is not such a huge surprise. The surprises are that a motorcycle like an R6 is a street-legal machine complete with lights, turn signals, legal noise, and emissions levels; it is sold with a warranty against mechanical failure and Yamaha offers it to the public for just over nine grand, about the price of a rearview mirror on one of today's F/1 cars. In the pocketbook, the two entities couldn't be more different. And in the end we like the differences just as much as we do the similarities. M

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