Simulation Spurs Yamaha's MotoGP Success

Simulating for Track Speed

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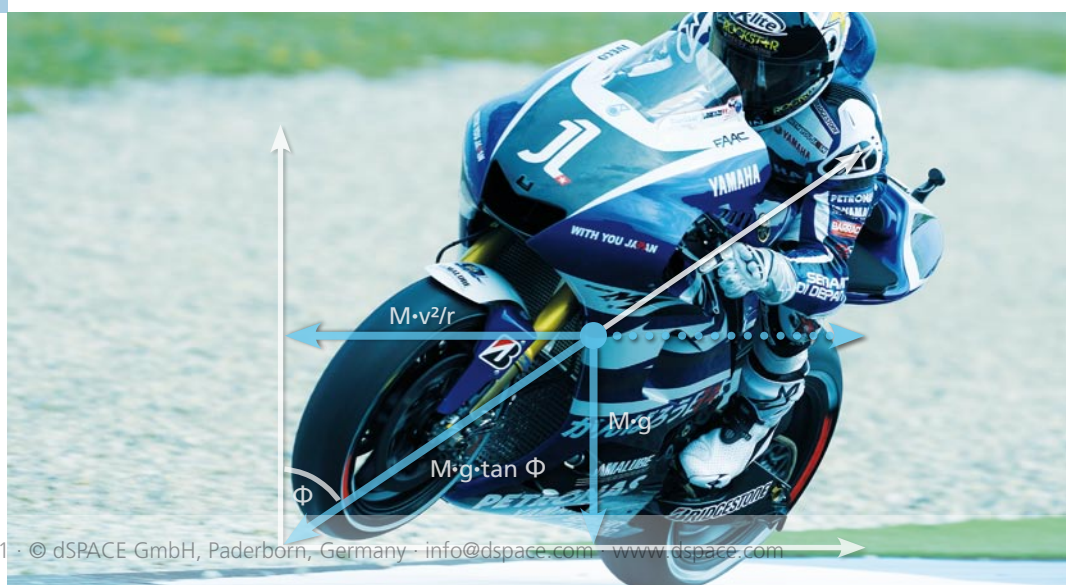
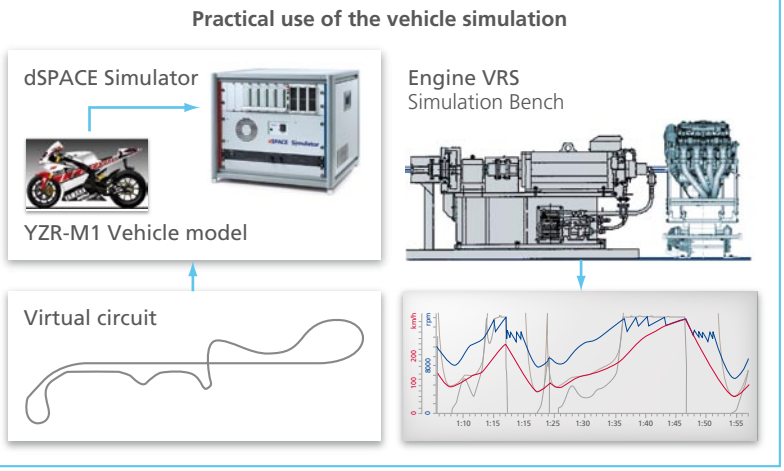
MotoGP 2011

The MotoGP triple crown is a remarkable achievement in the world's top motorcycle sports class. Since 2008, the Rider, Constructor and Team titles have belonged to Yamaha. The company relies on simulation techniques to continue its success.

Yamaha MotoGP Activities

Yamaha entered the motorcycle manufacturing market as a late entrant in 1955, the year Japan's motorcycle history really began. In 1961 Yamaha began participating in World GP road racing, and 2011 marks the company's 50th year of GP racing. Over this half century of road racing, Yamaha has continued racing in different forms and has won many titles, despite several withdrawals from the racing world. Yamaha carved out a glorious history along with a string of champion riders such as Phil Read (UK), Giacomo Agostini (Italy), Kenny Roberts (USA), and Wayne Rainey (USA). Behind this history are the unceasing efforts of Yamaha's technical staff and a spirit that refused to be daunted by failure. In particular, over these many years, Yamaha has needed to constantly adopt leading-edge technologies to swiftly adapt to numerous changes in regulations and maintain a high level of competitiveness, and has introduced various innovative development approaches.





Schematic of the simulation environment based on dSPACE Simulator and a dynamometer with test vectors from real race tracks.

Approaches for Developing MotoGP Machines

When Yamaha motorcycles are being developed, developers try to share the values that emerge from the rider-machine unity where the machine responds to the rider's will and feeling for the bike, and from the man-machine sensibility that expresses the rider's joy arising from this sense of oneness. To embody this man-machine sensibility, two engineering ideas have been systematized. These are GENESIS in the mechanical field, and G.E.N.I.C.H. in the electronic control area. As a MotoGP machine, the YZR-M1 is designed to realize these ideas at the very highest technological level, to support the rider's will and feeling for the handling of the machine, and to achieve the very best performance. While upgrading each element of the chassis, engine, and control system, the developers strive day by day to help the riders go faster by working with them, while the riders bring out all the performance the tires can deliver. MotoGP races are short-distance sprints that last about one hour.

The MotoGP machine is designed and manufactured to allow its capabilities to be maximized over that short period. The durability that is a part of racing over long distances has never been necessary.

Coping with Regulations and Durability Requirements

Over the last few years, however, regulations have restricted the number of race machines in an effort to cut operating costs, and durability and reliability are now more important than before. When limits were imposed on the total amount of fuel per bike in each race in an effort to address environmental problems, it became necessary to reduce loss in a range of areas, including friction loss. To achieve this, various new mechanical systems and control methods were tried. So that a machine can really be ridden safely, reliability and safety must be properly verified, as well as conformance, before the machine is ridden. And to shorten the development cycle, it is now important to carry out desktop checks with a virtual vehicle where possible. The success rate of systems that have been produced after adequate checks is rising and as a consequence make-over rates are falling. Even where early-stage checks have taken considerable time, even more time has been saved in the long run.

Development Environment Outline

Yamaha's race division has begun using simulation technologies to make the maximum use of limited resources. Part of this involves durability testing on the simulation bench and the use of hardware-in-the-loop (HIL) systems for control systems development.

Durability Testing using a Simulation Bench

Engine durability testing involves driving in a simulated pattern. The bike's movements are replicated using a physical model of the bike, and a dSPACE simulator is used to run a dynamometer control system. The simulation bench can be a kind of HIL system where an actual engine is used for closed-loop hardware testing. Thanks to this system, durability testing on a test course or chassis dynamo can be eliminated, and engine durability testing can be conducted just on the simulation

> "By using dSPACE Simulators in the development of engines and control systems, we have noticed a significant improvement in development precision and efficiency."
>
> *Noboru Yabe, YAMAHA MOTOR CO, LTD*

Yamaha's MotoGP Success: Winning the Triple Crown Three Times in a Row

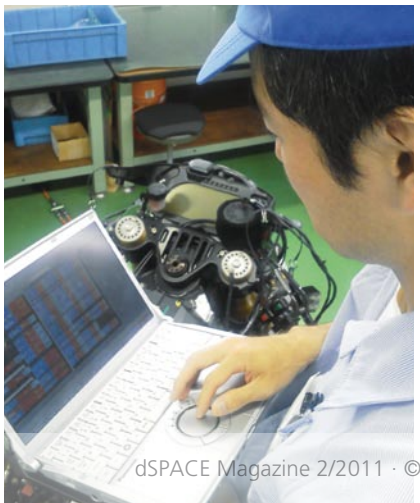
In 2002, with the emergence of the new-look MotoGP, Yamaha introduced its four-stroke YZR-M1. That year, Max Biaggi (Italy) notched up two wins on this machine but stopped short of taking the title. And in 2004, the third year of the new MotoGP, Valentino Rossi (Italy) chose Yamaha as his race mount. By now, the YZR-M1 had evolved to feature the crossplane-type crankshaft engine. In his first year of racing for Yamaha, Rossi took the championship title with a total of nine wins in the series. He took the World Championship GP title in 2005, 2008, and 2009 with Yamaha. The rider tipped to take over Rossi's mantle as the new ace was Jorge Lorenzo (Spain), who signed on with Yamaha from 2008. In 2008 he recorded a win at the start of his MotoGP career and achieved a ranking of 2nd in 2009. Then in 2010, Lorenzo recorded podium finishes in 12 races in a row, starting from the season's curtain-raiser, a reliable performance that earned him his first championship title. In 2010, Yamaha achieved a triple crown for the third year in a row, taking the Rider, Constructor, and Team titles and capping a winning streak that began in 2008. Now, in 2011, the 50th anniversary of Yamaha's entry into world GP racing, all eyes are again on Yamaha and its powerful team once more poised to dominate the world of MotoGP racing.

bench. As a result, the development cycle is considerably shortened and costs associated with running actual bikes are reduced. Because development precision improves and fewer prototypes need be produced, the reduction in total costs is considerable.

Control System Development

With engine control systems becoming more complex every year, dSPACE HIL systems are used to verify the functions of programs and hardware. For example, it is virtually impossible to conduct test drives under what are normally inconceivable conditions such as sensor failure. This is why HIL systems, which can simulate these conditions and run tests under them, are essential for the development of MotoGP machines. On the race circuit, problems such as conformance incompatibilities can occur from time to time. dSPACE HIL systems can also be used to address such problems. When implementing a measure to deal with a problem, it is necessary to run tests that replicate the driving conditions under which the problem occurred to ensure the measure is tested thoroughly. dSPACE simulators have proved effective tools in this situation too.

Left: Controlling vehicle features by software is a common technique for advanced race machines.
Right: For the highest efficiency in controller development, race engineers rely on simulated test runs directly at their desks.



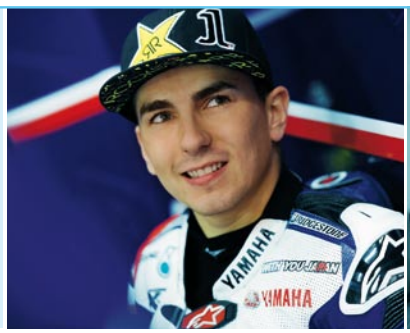
Race Machine YZR-M1: Technical Data

Engine:	Liquid-cooled crossplane crankshaft inline four-cylinder, four-stroke
Top speed:	In excess of 320 km/h
Power:	Over 200 horsepower (147 kW)
Transmission:	Six-speed cassette-type gearbox, with alternative gear ratios available
Chassis:	Aluminum twin tube delta box, multi-adjustable steering geometry/wheelbase/ride height. Aluminum swing arm.
Suspension:	Ohlins upside-down front forks and Ohlins rear shock, all adjustable for pre-load, high- and low-speed compression, and rebound damping. Alternative rear suspension links available.
Wheels:	MFR Forged Magnesium 16.5 front, 16.5 in rear
Tyres:	Bridgestone, 16.5 front, 16.5 in rear, available as slick, intermediate, wet and hand-cut tyres
Brakes:	Brembo, two 320-mm carbon front discs, two four-piston calipers. Single 220-mm stainless-steel rear disc, twin-piston caliper.
Weight:	150 kg (in accordance with FIM regulations)

Perform under Ultimate Conditions

Customer demands relating to Yamaha products – not just race products – are becoming more difficult to satisfy every year. As well as cheaper bikes, customers want machines that are more comfortable and enjoyable to ride as well as fuel-efficient. It has become very clear that simulation-technology-based testing methods can be a highly efficient way of satisfying multiple demands like these in one fell swoop. Because race machines, in particular, perform under ultimate conditions, conducting test drives under the extreme parameters required can present difficulties. Within the world of simulation, safe testing is possible. And product safety levels can be improved as large numbers of tests can be conducted. In this sense, the value of dSPACE's simulation products is

Outlook: 2012 1000cc YZR-M1



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Yamaha Factory Racing riders Jorge Lorenzo and Ben Spies comment on the 2012 1000cc YZR-M1 after testing it at the Misano circuit in San Marino.

"We've been working on the electronics to help in the braking area but mainly I've been getting used to the riding style of the bike and also adapting the bike to my riding."
Jorge Lorenzo

"We've got a lot of data now for the engineers to go away and work on the next step for our next test."
Ben Spies

"We expect dSPACE to lead innovation in the HIL area."

Noboru Yabe, YAMAHA MOTOR CO, LTD

increasing all the time. On the other hand, the costs associated with testing and test equipment are also rising. The more complex the testing, the higher the cost of training the user to use the equipment properly. It will be necessary to improve the functions of test equipment, but it is possible that the associated costs will fall.

Feedback on dSPACE products

At Yamaha we have come to use HIL simulators in the development of engines and control systems, and have noticed a marked improvement in development precision and efficiency. In the past, we needed a racing circuit to see how we were doing, and at times, couldn't see how we were doing anyway. But once we used a simulator we could see what was happening.
As a result, the riders have been able to concentrate on their riding and have achieved good race results.
Although our developers use dSPACE products for long periods at a time, there are few malfunctions or problems, and the products are very reliable and useful.
It is obvious that introducing new technologies into the development process causes new complexities and ties up resources. But the benefits of a HIL system definitely balance these.
Simulation technology is unlikely to stop advancing in the future, and the value of using HIL systems as test equipment seems to be growing. In the future, we expect dSPACE to continue to lead technological innovation in this area.

Noboru Yabe
MotoGP Group
YAMAHA MOTOR CO, LTD.

Noboru Yabe
Mr. Yabe is senior engineer in the MotoGP group at Yamaha Motor Co., Ltd, in Shizuoka, Japan