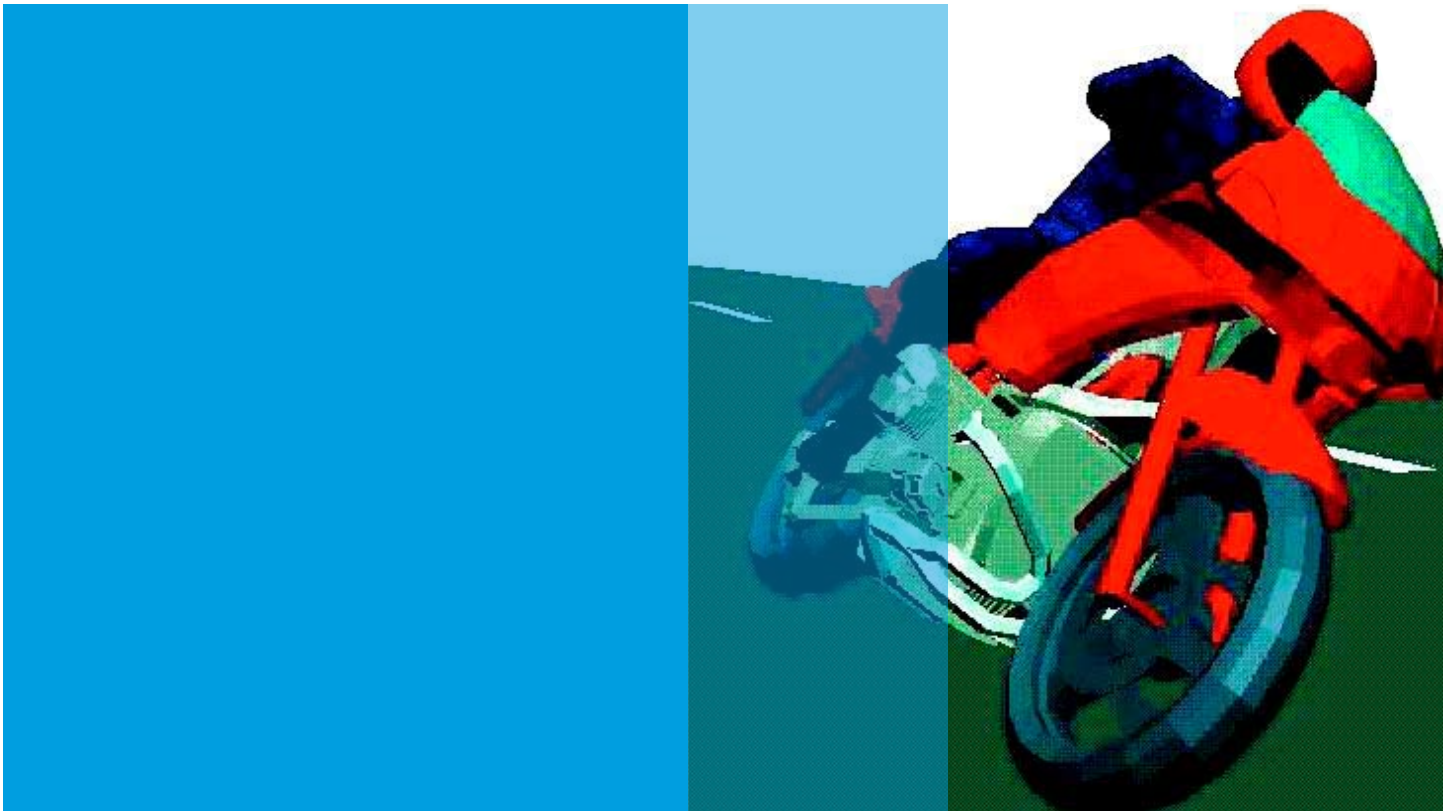


# BMW Uses Computer Simulation to Ensure Motorcycle Stability



BMW engineers are using computer simulation to ensure stability of motorcycles by accurately defining structural design requirements. BMW achieves greater assurance of meeting stability requirements by using computer simulation to evaluate motorcycles throughout a wide range of potential dimensions. The basic idea is that engineers can determine with precision the range over which desirable stability characteristics are maintained, rather than just the few cases in which it is practical to evaluate using physical testing.

### Measuring stability

In the area of maintaining stability of conventional motorcycles, engineers have established a series of tests that measure the wobble, weave and kickback of every new model before it is released for production. In one typical test, the driver propels the bike at a high level of speed then suddenly moves and releases the steering wheel. The purpose of the test is to evaluate the period of time during which the bike stops weaving and resumes a straight path.

The test used to measure wobble is similar except that instead of moving the handlebars the test driver makes a quick lateral motion with his hips. Both of these tests measure the ability of the bike to dampen excitations introduced by the driver. Kickback, another important stability measurement, measures of the response of the motorcycle to excitations introduced by the road profile. This test measures the possibility that the suspension system of the bike will be excited by bumps that are spaced at certain distances on the road.

### Limitations of physical testing

BMW engineers use these tests and many others to qualify the stability of their products. They provide a nearly perfect measurement of the stability characteristics of a prototype or production motorcycle. But physical tests are so expensive and time-consuming that they limit the number of design alternatives that can be considered. Prior to beginning testing, a physical prototype of the motorcycle design must be built. The motorcycle also usually needs to be instrumented in order to collect test data. Testing is subject to delays caused by weather and driver and track availability. This was another major reason why BMW engineers began nearly a decade ago to investigate the use of computer simulation to evaluate the stability of alternate motorcycle designs.

### Evaluating multiple design alternatives

With computer simulation, it's relatively easy to change the motorcycle design parameters being evaluated, to lengthen

the wheelbase or reduce its weight for example. This makes it possible to evaluate many different configurations. These types of changes are expensive and time-consuming to make during physical testing or after the vehicle is produced. Computer simulation also provides the opportunity to evaluate the performance of equipment under extreme conditions that could be dangerous, damaging and expensive to perform on the test track. Computer simulation also provides more data in most situations than physical testing. Physical testing results are usually limited to a small number of locations where sensors are placed while computer simulation provides data from throughout the problem domain.

At the time that BMW engineers made their evaluation there were just a few simulation software packages capable of evaluating a mechanism as complex as one of the company's high-performance motorcycles. The engineers evaluated some of these software packages and selected DADS mechanical system simulation software from LMS CADSI (Computer Aided Design Simulation, Inc., Coralville, Iowa). This advanced multi-body dynamics simulation software is employed throughout the world to create virtual prototypes of vehicles and other mechanical systems with general constraints, gravitational forces, and forces due to contact. A key advantage of DADS is its open architecture that makes it relatively easy to create user-defined subroutines to expand the capabilities of the program.

### Tire and driver control subroutines

Over the years, BMW engineers have developed two subroutines that make it possible to measure the three important stability characteristics mentioned above. One subroutine models the actions of



the driver. It controls the velocity of the motorcycle, moves the handlebars and can operate the brakes. Another important subroutine models motorcycle tires by determining the force applied between the tire and the road. This subroutine was developed in cooperation with universities and other companies including Metzler and Pirelli. Actually, the DADS program includes a tire model, however, BMW engineers wrote their own because motorcycle tires can roll up to 50 degrees, creating forces that can't be captured in a conventional model. This subroutine is dynamic so it captures the phenomenon called relaxation in which tire forces don't appear instantaneously but rather develop over a short period of time.

The engineers developed a model that can be modified to evaluate the performance of any motorcycle model. The number of degrees of freedom of this model can vary but are typically about 26. The major elements of the model include the mainframe, lower and upper fork, telelever, front and rear wheels, swing arm, and several smaller components. The driver consists of two separate elements comprising the upper and lower body that are connected with a spring damping mechanism that allows the driver to swivel its upper body. The tire and driver control subroutines

mentioned above are also important parts of the model. Mass properties, including the center of gravity and moments of inertia are added to the model. BMW engineers address stiffness issues by incorporating springs and shock absorbers and structural flexibility into their model.

### High level of accuracy

This model has proven the ability to simulate common stability tests with a very high level of accuracy. In fact, engineers consider that the simulation results are at least as accurate as the measurements they are able to take on the test track. For example, in the weave and wobble test, the simulation provides a damping measurement that is accurate to approximately one second. The major advantage of the simulation model is that it permits engineers to measure far more product variations than would be possible if each one had to be built in the prototype shop. As a result, BMW engineers are now able to specify structural design requirements, such as stiffness, mass distribution, etc. that will ensure the stability of the end product. Simulation results are validated many times on the test track before a motorcycle is brought to market.

In addition to providing an extra level

of quality assurance, simulation has also streamlined the design process for new motorcycles. Engineers now use computer simulation to evaluate the performance of alternate design concepts long before they produce the first prototype. The speed and convenience of simulation makes it possible for them to analyze a wide range of alternatives in far less time than was required in the past using the traditional cut-and-try approach. The result has been both a faster rate of product innovation and a reduction in the time required to bring new designs to market.

As this application demonstrates, computer simulation can increase quality by allowing designers to consider more accurately specify design requirements. The net result of using simulation is that BMW engineers can produce better motorcycles in less time.

The success of this technology is so well accepted at the firm that engineers now have several projects underway to improve the effectiveness and breadth of their simulation models. They are currently developing the capability to determine the performance of a design in driving over a particular road profile. And, they are improving the accuracy of their models by incorporating flexible elements that more accurately simulate the response of the frame. ■



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