Simulation helps Harley-Davidson improve motorcycle handling

By Ray Fossman, Manager of Applied Mechanics/Structures Lab
Tom Spehert, Senior Engineer Harley-Davidson Motor Company Milwaukee, Wisconsin

LMS®
ENGINEERING INNOVATION

Harley-Davidson is reducing engineering costs by using off-the-shelf mechanical simulation software to analyze motorcycle designs. Computer simulation makes it possible for engineers to configure a new motorcycle and test its handling in a few hours on the computer, compared to weeks or even months using the conventional build and test approach.

Additionally, engineers have developed a graphical front-end that allows them to streamline the design simulation process simply by typing in new parameters such as front wheel weight and then run standard tests such as straight line weave damping. By giving them the ability to evaluate more design alternatives than ever before, simulation helps engineers in the motorcycle design process.

Harley-Davidson is the only major American-based motorcycle manufacturer and a leading global supplier of premium quality, heavyweight (651 cc+) motorcycles. The product line includes 20 traditional, factory custom and touring motorcycles as well as police and military motorcycles. Harley-Davidson product names are among the best known in the industry including Sportster, Super Glide, Low Rider, Softail, Dyna Glide, Wide Glide, Road King, Electra Glide and Tour Glide. The company employs approximately 5,000 and has 1,079 dealers worldwide including 592 in the United States, 260 in Europe, 84 in Canada and 40 in Japan. Of its total production volume of about 120,000 motorcycles, 29% are shipped overseas to 30 different countries. While it is impossible to eliminate the possibility of accidents, Harley engineers go to extreme lengths to qualify the safety of their vehicles. Whenever they introduce a new model or derivative of an existing motorcycle, they perform a series of tests to evaluate its handling. A typical example is the straight line weave damping test in which a test driver accelerates the motorcycle to 70 mph, takes his hands off the handlebars and crosses them on his chest, then makes a quick lateral motion with his hips. This maneuver causes the motorcycle, as well as any two-wheeled vehicle, to begin to weave back and forth. The question is: how quickly does it resume a straight path without any action on the part of the driver? Harley engineers use this test and many others to qualify the handling of their motorcycles.

The problem with physical tests like the one described above is that they are expensive, dangerous, and they take a considerable amount of time. First of all, a prototype of the design must be constructed in Harley Davidson's prototype shop. Then, the motorcycle has to be taken out to the track and tested. The test can also be subject to further delays due to the weather, track and rider availability. For many of these tests, additional time and money is required to instrument the vehicle and analyze the data that is collected. Clearly, the amount of time and money required to perform these physical tests limits the number of alternative design configurations that Harley engineers can consider. For that reason, engineers made the decision to begin investigating the use of computer simulation to evaluate motorcycle handling.

Easy to use software

Their investigation identified two main commercial software packages that are used by engineers in the automotive, off-road equipment, and aerospace industries to simulate and animate 3D dynamic mechanical systems. They developed a benchmark problem that involved simulating a basic motorcycle design and evaluating its performance in a test similar to the one described above. They invited representatives of each of the two simulation software companies to visit Harley and solve their benchmark problem. Only one of these programs, DADS, the mechanical system simulation software from Computer Aided Design Software Inc. (CADSI), Coralville, Iowa, was able to solve the benchmark problem. In addition, this program also appeared to Harley engineers to be considerably easier to use. Based on these considerations, management made the decision to purchase DADS. The FLHT Electraglide Standard is one of several current models that have been designed with the assistance of Simulation Driven Design. This particular motorcycle is a cruising bike with a telescopic-suspension front end. At the time that the analysis group was brought into the design process, many

DADS simulates the behavior of the straight line weave maneuver.

DADS provides the ability to capture images of the motorcycle at all time steps during a lane change.

aspects of the vehicle had already been finalized. The main areas that were still open to change were the position of the rider and accessories. Analysts were asked to evaluate as many design alternatives as possible in terms of their effect on handling and provide their recommendations.

Modeling process

The engineers began by modeling the motorcycle in DADS. They created the basic geometry of the motorcycle using the computer aided design capabilities included in the simulation software. Then mass properties, including the center of gravity and moments of inertia, were added and the properties of the tires were modeled. Harley engineers addressed stiffness issues by incorporating springs and shock absorbers into their model.

Once they had completed their model, engineers simulated a series of tests that help evaluate the handling of the motorcycle. To simulate the weave test mentioned above, they simply define the heading and speed of the motorcycle and apply a lateral force between the rider and his seat to begin the weave maneuver. An advantage of the simulation approach is that engineers run the simulation at exactly the same speed and apply the same amount of lateral force every time. Engineers can view animations of the test that show how long it takes the motorcycle to return to a straight line path. They are also able to obtain a vast quantity of engineering information from the simulation, far more than they can obtain in physical testing, such as the vehicle speed and bearing at any instant during the test.

By using DADS, Harley engineers are able to simulate the handling of the motorcycle during a lane change or j-turn as well as the weave maneuver. Simulation results werevalidated against physical experiments prior to adopting the new analysis methods in the design process.

Evaluating alternate designs

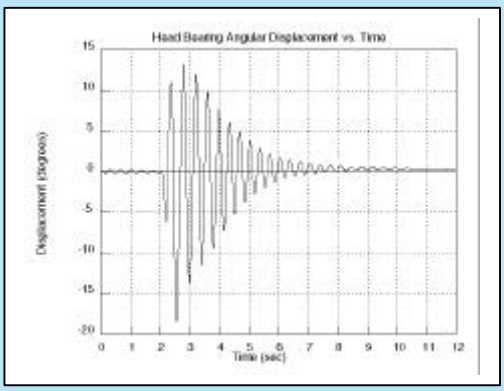
After they completed their initial simulation, engineers ran a series of design iterations to evaluate alternate design concepts. The software made it possible for them to easily make changes to their model and then re-run the analysis to determine how their changes affected the motorcycle's handling. For example, engineers tried a number of different positions for the driver's seat which can have a big effect on handling because it changes the weight distribution. They also looked at several accessories, including alternate muffler systems. They developed recommendations, which included moving the driver's seat forward from its original position, that qualified the handling of the motorcycle.

After several successes such as this, Harley engineers decided to expand their involvement with simulation. They worked with CADSI consultants to develop a custom graphical front-end to the DADS program that automates the analysis process.

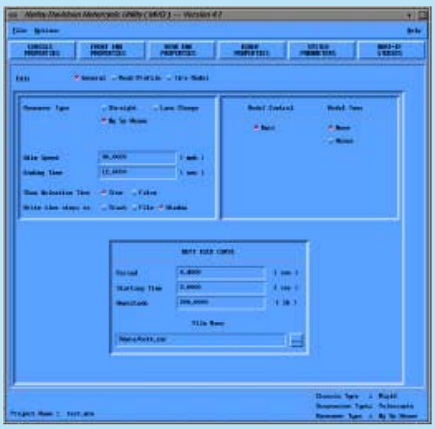
The graphical front-end was tailored specifically for handling. Required inputs are minimized and described with handling nomenclature, allowing a user who is unfamiliar with DADS to easily evaluate design alternatives. The engineer interacts with the program through drop down menus that allow changes to parameters of the design. For example, if the engineer selects "front-end" from the menu the screen fills with the parameters that define the front end of the vehicle such as front wheel weight and spring and damping rate of the shocks. The engineer simply enters parameters to define the design of the vehicle they want to evaluate and then selects the maneuver that they want to simulate. The program automatically creates the model, runs the analysis and prints out the results. Using this program, it's possible for engineers to develop and simulate a new design in less than an hour, far less than the weeks that were required with the old build and test approach.

Since developing the graphical user interface in DADS, Harley engineers have begun simulating nearly all of their upcoming models from a very early stage in the development cycle. By using computer simulation to evaluate alternate design concepts, Harley-Davidson has compressed the design cycle to a remarkable degree. The speed and convenience of mechanical simulation makes it possible to consider many times the number of design alternatives that the company was able to evaluate in the past using the build and test approach. The results? Engineer's design better handling bikes in less time than ever before. Harley-Davidson riders say: "the best way to get there is to just go." With Simulation Driven Design, Harley-Davidson engineers are getting there in less time and with higher quality motorcycles than ever before. ■

Physical testing of a Harley Davidson.



Results of the weave simulation show the time it takes for the motorcycle to regain stability. Results can include positions, velocities, accelerations, and loads.



CADSI engineering consultants worked with Harley Davidson to create a user-interface to DADS tailored for motorcycle handling.

LMS INTERNATIONAL
Researchpark Z1, Interleuvenlaan 68
B-3001 Leuven [Belgium]
T +32 16 384 200 | F +32 16 384 350
info@lmsintl.com | www.lmsintl.com

Worldwide

For the address of your local representative, please visit www.lmsintl.com/lmsworldwide

LMS is an engineering innovation partner for companies in the automotive, aerospace and other advanced manufacturing industries. LMS enables its customers to get better products faster to market, and to turn superior process efficiency to their strategic competitive advantage. LMS offers a unique combination of virtual simulation software, testing systems and engineering services.

LMS is focused on the mission critical performance attributes in key manufacturing industries, including structural integrity, system dynamics, handling, safety, reliability, comfort and sound quality. Through our technology, people and over 25 years of experience, LMS has become the partner of choice for most of the leading discrete manufacturing companies worldwide.

LMS is certified to ISO9001:2000 quality standards and operates through a network of subsidiaries and representatives in key locations around the world.

LMS®
ENGINEERING INNOVATION