Simulation commands

Engineers at the world's largest OEMs use kinematics and compliance (K&C) test rigs to measure suspension behavior for use in CarSim simulation software, and then simulate thousands of tests evaluating advanced controllers and other vehicle components.

One of the tests that they wanted to simulate in the past was the K&C test itself, to confirm that the results from simulated vehicles match those from the actual test rig. However, a problem was that K&C test conditions are far different from the road tests that CarSim was designed to replicate. With the introduction of CarSim 7, K&C simulation can be obtained with just a few commands in the new VehicleSim (VS) Command Language to add the effects of the clamps and motion constraints of the test rig.

This example is typical of the conflicting requirements most users have for simulation software: it must be accurate, simple to use, but also very detailed in one specific area. Tire specialists want a sophisticated tire model; powertrain engineers need detailed engine models; test engineers want precise control over test procedures and sensors. And, engineers getting suspension data
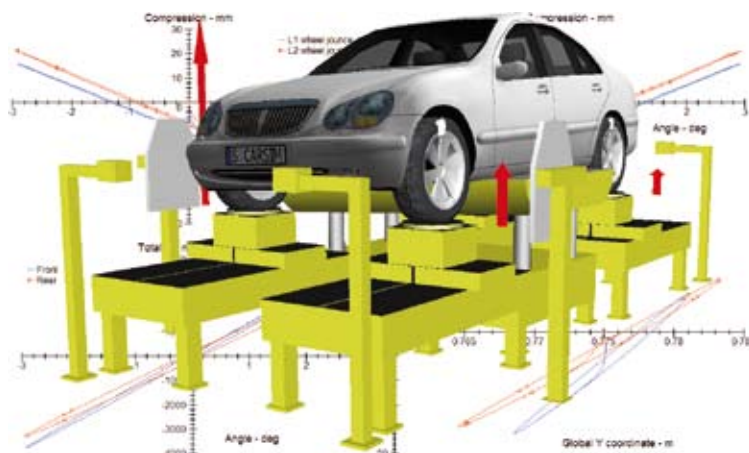

FIGURE 1: **CARSIM 7 KINEMATICS AND COMPLIANCE TEST RIG MADE BY ADDING BODY CONSTRAINT FORCES**

from a K&C rig might want to simulate the rig to confirm that their process was correct.

These conflicts have grown over the past few decades as vehicle dynamics simulation has evolved from a tool used by only a few specialists to one used by thousands of engineers in the vehicle and component development and testing process. Diverse requirements make it impossible to have a single simulation model that satisfies all users. The solution is to have a "core" model that can be extended to cover these special needs.

The international standard for many OEMs and Tier 1 suppliers is CarSim, from Mechanical Simulation Corporation. CarSim combines high-fidelity vehicle models with a simple point-and-click GUI and high-speed operation. CarSim works well with other simulation environments, allowing advanced users to extend the core vehicle models with other software. For example, control concepts described in Mathworks Simulink are routinely tested with CarSim vehicle models. This form of model extension has grown from a specialized method for experts to

FIGURE 2: **OUTRIGGERS ARE ADDED USING FOUR SIMPLE VEHICLESIM EQUATIONS TO ASSESS A VEHICLE'S PROPENSITY TO ROLL OVER WITHOUT COSTLY PHYSICAL TESTING**

FIGURE 3: **CALCULATOR AND INTERPOLATION OPTIONS FOR TABLES**
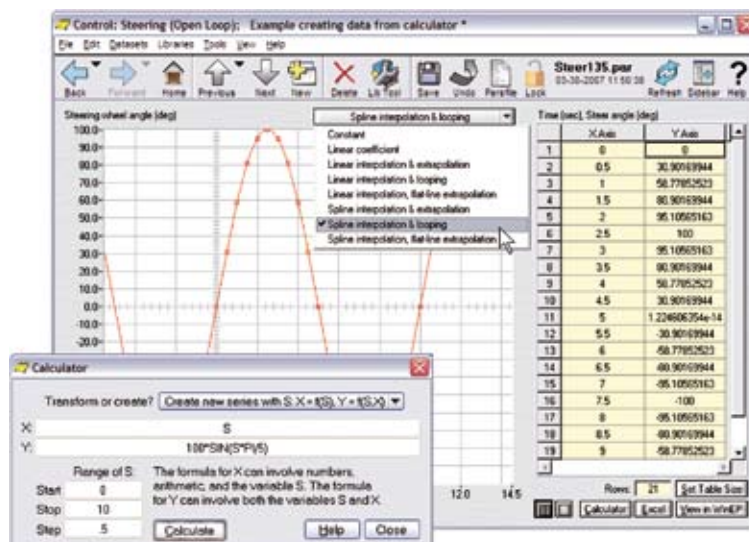
a broad approach taken by most users. To provide better support for a wider range of simulation requirements, the new VehicleSim (VS) Command Language has been introduced with CarSim 7 to more easily extend and customize the math model, while maintaining a simple user interface and high speed.

As background, it should be mentioned that two basic approaches are used for simulating vehicles today. In the first method, a generic multibody program is used to both build the model and make the simulation runs. Users can extend the models as needed, so in principle almost any level of detail can be included. However, the general-purpose tools are not practical for use by anyone other than simulation specialists. Another limitation is that the solution methods do not work for real-time applications such as driving simulators and hardware-in-the-loop (HIL) testing. Under the second method, CarSim uses custom programs with equations of motion optimized for representing the mechanics of specific classes of vehicles. These compiled programs run about 50 times faster than the same model running in a generic multibody program, making CarSim a good deal faster than real-time. The GUI is intended for engineers who understand vehicle systems, but not necessarily simulation

details. The combination of the high efficiency and simple GUI allows the same models and datasets to be used for a broad range of applications in design, development, simulation, HIL testing, and driving simulators.

Equations in previous versions of CarSim were machine-generated with AutoSim, a symbolic multibody program. AutoSim has been replaced with VehicleSim, an environment that generates equations just like AutoSim, and also a run-time library with modeling capabilities for CarSim 7 users. The VS command language allows users to define new variables, add equations, extend existing equations, and change the units associated with variables.

For example, limit handling tests often require outriggers to prevent rollover in tests. While not required in most simulations, engineers can extend the CarSim model to include outriggers in order to assess their influence on vehicle performance or to test effectiveness. Only four VS commands are required to define equations for external forces from outriggers hitting the ground and generating restoring forces.

Although the new VS commands can be used to replace external software, other new features in CarSim 7 provide even more integration capability to support outside software. Take, for example, steering wheel angle control. Although a

native value is calculated internally in CarSim, a user who extends the model with a controller defined in Simulink has the options to replace the native value, add to the native value, or multiply with the native value. These options exist for over 100 of the model variables, and allow advanced users to define subtle enhancements to the program with incremental extensions.

Model parameters can be defined using symbolic equations that can draw from thousands of other model parameters and variables. For example, dimensions can be set as functions of overall wheelbase; coefficients on one side of the vehicle can be set to be equal to the corresponding coefficients on the other side (or their negative values). Many non-linear relationships between two or three variables are represented by table functions. Users can now specify calculation details at run time, such as whether the dependent variable should be constant, linear, or non-linear; and if non-linear, which type of interpolation and extrapolation methods should be used.

The math model solvers are provided as standard DLL files that support the VehicleSim application program interface (API), and can be used directly with many environments, including Windows commands, the CarSim database, Simulink, LabView, and others. The CarSim database browser works as a COM server and can handle automation methods defined in most programming and script languages, including MATLAB, PERL, Visual Basic (and Excel), C/C++, and others.

CarSim 7 has many improvements in addition to the new VehicleSim features. The multibody interactions between tire, road, steering, and suspension now include more detail for extreme steering and 3D ground conditions, and advances have been made in the GUI.