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Vehicle Dynamics Software – Today and Tomorrow

The revolution in automotive product development that combines electronic controls with mechanical chassis systems has challenged the developers of vehicle dynamics software to envision how their tools can better serve engineers. In addition to the traditional usage of simulating vehicle dynamics tests, the software is now helping electrical engineers and component designers evaluate how various controllers interact with the vehicle under a wide range of conditions. Starting with Brake and Traction controls, vehicle simulations were extended to include Electronic Stability Control (ECS) systems performing sophisticated vehicle dynamics management. These include active steering and suspensions, powertrain controls, yaw and roll stability controls, radar and video systems, roadway infrastructure-to-vehicle communications, and vehicle-to-vehicle communications. The design of CarSim, TruckSim and BikeSim – software products from Mechanical Simulator Corporation – illustrate how these systems are simulated and tested long before actual prototypes are available.

Usability – Some vehicle dynamics software has evolved from general-purpose multi-body dynamics software, resulting in programs that are difficult to configure and use by engineers who are not specialists in multibody dynamic theory. To make software more accessible to other engineers in the automotive industry, CarSim was designed to emulate the physical test world using the paradigm of selecting a vehicle, choosing the control inputs that represent the desired maneuver, and selecting the test environment. The simulated vehicle is assembled from parts in the software database, just as a real vehicle is assembled from physical parts. Once the test "run" is made, the user can evaluate the results via animations and plots of engineering data. User-friendly GUI data input screens are pre-filled with sample vehicles, subsystems, roads, and test procedures. New users can run simulations immediately, and rapidly refine the vehicle description by swapping parts and changing specific parameters of interest.

Flexibility – No vehicle dynamics model can serve the needs of every system specialist without becoming too complicated for general use. Recognizing this, CarSim was designed to allow users to extend the vehicle model or substitute any of the internal system models using Simulink or user-supplied C-code. For example, the designer of a brake controller will typically replace the internal model of the brake hydraulics and controller with a more detailed model in Simulink or other software, relying on CarSim to provide the rest of the vehicle model and the overall testing environment (road geometry, friction, wind, driver controls, etc.).

Design Analysis – In the design stages, engineers are often faced with "What if" questions. What are the consequences to ride, handling and general dynamic behavior if a suspension needs to be modified for packaging reasons? This is the traditional role envisioned for most vehicle dynamics software. Qualitative answers are quickly and easily provided in CarSim by means of animations of the vehicle in the maneuver.

Quantitative answers are available from automated plots of over 500 calculated variables, many of which would be difficult or impossible to measure experimentally. CarSim also provides easy methods for comparing two cases (using overlays) in both the animation and plotting environments.

Controls Development – One of the most important roles played by vehicle dynamics simulation software is in development of the multitude of control systems (ESC, ABS, TCS, ARC, 4WS, etc.) found in modern cars. Simulink is an example of the software in which such controls are conceptualized and developed. To test control systems, engineers need a vehicle dynamics model that can translate performance of the control system into real world behavior of the vehicles. CarSim has been designed to interface readily with Simulink, C-code models, and other modeling software, such as AMESim. OEM's and Tier 1 Suppliers have already linked many of the currently planned sensors, actuators and control strategies into CarSim. With the vehicle model represented as an S-function in Simulink, engineers can design and refine the control system in a prototype vehicle over a broad range of vehicle trim conditions, running any test procedure under a range of environmental conditions. Most of CarSim's users have even correlated their computer simulations to actual proving ground results for a wide variety of vehicles. Suppliers send CarSim data sets for new hardware and software control concepts to their OEM customers via email, without releasing any propriety information.

Roads — Test roads from anywhere in the world can be easily added to the CarSim database. New test roads have even been designed in CarSim to optimize measurement of vehicle performance extremes. Partnerships developing new intelligent traffic system standards can use CarSim to exchange input data and results between all of their OEM, Supplier, University and Research members.

Hardware in the Loop – There always arrives a stage in which engineers need to test prototype hardware components before design release. Waiting for an actual vehicle as a test bed for the confirmation process is simply not practical in today's accelerated product development cycle. Vehicle dynamics software can be used in place of the test mule if high fidelity simulation models include real time capability. CarSim, which has always been faster than real time, works with any hardware-in-the-loop (HIL) system. Customers are routinely using CarSim RT with ADI, A&D, dSPACE, ETAS, Fujitsu-TEN, National Instruments, Opal-RT, and PhaseX systems. Since the software and models are identical for CarSim in real-time and off-line versions, CarSim users can easily transfer data into real-time systems and quickly identify changes in behavior due to the physical hardware in the loop.

Driving Simulation – Simulation capability provides the engineering community with the ability to calculate and visualize the performance of the products they are developing. However, one essential item cannot be obtained by studying plots and statistics – the "feel" of the vehicle. Recent advances in driving simulator hardware in conjunction with CarSim enhancements bring this possibility within reach in many new applications. Desktop simulators can be inexpensive yet provide a powerful tool for both evaluating designs and training the engineering staff to perform such evaluations. For

example, high-fidelity steering wheel systems coupled with high-fidelity vehicle dynamics models provide an ideal environment for evaluation of the nuances of on-center steering feel. Such properties as backlash, torque gradients, etc. can be easily replicated in CarSim and related to vehicle properties. The prospect of training new engineers to become proficient steering system specialists by practicing experiences on a driving simulator is an exciting new development. CarSim is now used in a wide range of desktop and moving-base driving simulators.

Vehicle Dynamics Expertise – Modern software tools can integrate detailed vehicle dynamics knowledge into their 'Help" menus, and link this to any data screen variable. CarSim contains a 500-page manual describing all of the key vehicle dynamics equations and parameters, as well as their representations in CarSim. This form of education even helps non-vehicle dynamics people understand the important relationships and interactions between chassis systems and vehicle performance – from the normal driver to the racing enthusiast. A User Data Manual accessed from the "Help" menu provides information about typical and reasonable values of the parameters needed to specify a vehicle.

The Future – Complex electronic control systems with their links to visual and radar systems, GPS, and intelligent road infrastructure devices are expanding the challenges faced by chassis development engineers. CarSim software has enabled new design and testing procedures that can reduce product development time and costs, even while adding new safety features to reduce accidents. The desired community goal of zero accidents will continue to force rapid development and integration of these new systems in vehicles. CarSim is one tool designed to be easily used by anyone involved in these exciting engineering challenges.

MORE INFORMATION

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Quote reference VDI --------

Graphics and Captions

Figure 1 – CarSim's Run screen links to the vehicle, controls, environment, animator and plots
Figure 2 – Skid Pad maneuver with and without Yaw Contoller
Figure 3 – Simulink combines electronic controller models with the CarSim vehicle model
Figure 4 – CarSim operates desktop to full-vehicle driving simulators

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