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HYBRID SYSTEM RESPONSE CONVERGENCE (HSRC): AN ALTERNATIVE METHOD FOR DURABILITY HYBRID SIMULATION

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ABSTRACT - The boundary conditions for physically testing vehicles, vehicle systems, and components can be more realistically represented if the dynamics of missing components or environmental inputs are included as virtual elements within the overall test system, forming what is referred to as a "hybrid simulation" test. In addition to providing a more realistic test environment, hybrid simulation methods typically also allow accurate tests to be conducted without the requirement to first measure the direct road response for a particular vehicle configuration. This capability allows testing much earlier in the vehicle development process, and supports the frequent need to test a variety of component or vehicle setup variations without measuring or predicting new data.

Hybrid simulation test configurations generally attempt to integrate real-time models of the missing test system elements with physical test rigs employing high-speed closed-loop tracking control. These "real-time" implementations can provide a very realistic representation of the complete system environment. For many complex dynamic systems, however, real-time implementation can be difficult to accomplish. Some applications, such as vehicle durability simulation, require more much more detailed models and higher-bandwidth multi-axis test system performance than can currently be realized in real-time.

To enable more complex test scenarios, a new hybrid simulation method, "Hybrid System Response Convergence" (HSRC) has been developed that preserves the characteristics of real-time coupling between physical and virtual test components without requiring a real-time implementation. To accomplish this, the multi-point interface dynamics between the physical and virtual systems are direct coupled in one dimension (i.e. force or motion) only. Feedback coupling in the alternate dimension is accomplished indirectly using an iterative error-reduction control strategy. When the feedback error has been reduced to an acceptable level simultaneous with the application of the forward input, compatible dynamics between the virtual and physical elements of the hybrid system will have been achieved. This results in a hybrid simulation that is equivalent dynamically to a real-time coupled configuration.

Without the real-time implementation constraint, the HSRC simulation method can utilize MBD or FE model configurations which are typically only used for off-line analysis. In addition, standard physical test systems and conventional test system controllers can be used. This provides the opportunity to leverage existing physical and analytical resources and expertise in the hybrid simulation approach, while ensuring compatibility of simulation results with all other phases of the organization's development process.

This paper introduces the HSRC simulation technique, and compares its implementation to more common real-time hybrid simulation techniques. Application opportunities for HSRC are discussed, and experimental results demonstrating the application of HSRC to develop a ¼-vehicle suspension durability simulation are presented.