

6 DOF Bench Test on a New Active Kinematics Rear Suspension for Functional Development

Isabel Ramirez Ruiz
Ferrari Spa

Dave Fricke, Thomas Stachel and Juan Garcia
MTS Systems Corp

ABSTRACT

To optimize the tyre contact patch in a sports car, Ferrari has developed an active camber and toe (ACT) system comprising of 4 actuators for the rear axle. This complex and completely new system is difficult to model accurately and for this reason, it was decided to combine a physical prototype with a full vehicle model to carry out the functional tests. The method of combining a virtual model with a physical test is known as hybrid simulation.

This functional testing of both the actuators and the vehicle dynamics logic will be performed on an MTS 6DOF bench test prior to physical track testing on a prototype vehicle using Ferrari facility in Maranello, Italy. In support of this functional testing, we will use hybrid simulation techniques with software and methods specifically developed. The planned hybrid test system described in the paper will allow dynamic coupling between the physical bench test and a modified full vehicle simulation model.

The full vehicle model provides the desired dynamic wheel center forces and parameters for the ACT position logic (which is implemented in a rapid prototyping ECU) to the bench test. The physical system responds, and the real displacement of the ACT system is read back into the full vehicle model to calculate the new wheel position, vehicle reaction and the resulting wheel center forces and moments.

This new ACT hybrid simulation implementation will allow testing of the system performance up to frequencies of 40 Hz as well as verification of the logic and safety systems.

CITATION: Ramirez Ruiz, I., Fricke, D., Stachel, T. and Garcia, J., "6 DOF Bench Test on a New Active Kinematics Rear Suspension for Functional Development," *SAE Int. J. Passeng. Cars - Electron. Electr. Syst.* 5(1):2012, doi: 10.4271/2012-01-0550.

INTRODUCTION

Due to the complexity of the active suspension in terms of unknown coupling variables and safety, Ferrari decided on a joint activity with MTS to test the complete system (full active rear axle) in the MTS 329 road simulator.

The scope of the project is to evaluate the capabilities of the active system, toe and camber actuators replacing passive links, on the 329 road simulator. The development will be performed in two phases:

- Level 1: Component control and dynamic behavior confirmation using conventional test methods.
- Level 2: Active suspension performance and durability evaluation by applying hybrid simulation using the Hybrid System Response Convergence (HSRC) technique which will be described later in this paper.

The project will be conducted using the following components:

- Ferrari's MTS 329 Road Simulator with FlexTest™ control system
- Ferrari F458 measurement and test vehicle
- Ferrari standard ADAMS full vehicle model using a custom durability tool
- Ferrari standard electromechanical actuator model in AMESim
- Ferrari dSpace simulator
- MTS custom HSRC modeling and control software tools within a modified RPC Pro™ environment.

COMPONENT CONTROL AND DYNAMIC BEHAVIOUR CONFIRMATION WITH CONVENTIONAL TEST METHODS

The objective is to confirm that all suspension actuators and active control system perform as expected under the applied load and motion conditions, and that the active-link system will operate safely and reliably prior to using the system in an actual test vehicle.

For the conventional test methods level we use the 329 axle rig and RPC Pro iterative methods. The RPC convergence method uses a Frequency Response Function (FRF) to identify the relationship between physical test rig control inputs and the response of the physical system. The RPC FRF is then used to iteratively reduce the response differences between the systems by adjusting the physical system inputs until compatible dynamic behavior is reproduced. The inverse of the RPC FRF is used to convert the convergence error between the system into a drive correction, and the process is repeated until the desired responses have converged to an acceptable error level.

ACTIVE REAL AXLE TESTING USING CONVENTIONAL RPC

Full-vehicle road simulators typically utilize a structurally complete vehicle as the test specimen. Ferrari's facility enables testing only one axle at time. This means that the vehicle contains all of the representative rear suspension components, toe and camber actuators and chassis. The specimen is excited via force and motion inputs directly at the vehicle spindles. Spindle force and moment measurements from Wheel Force Transducers (WFT) installed on the physical rig will be used as reference response for the RPC control process (Figure A1).

Three signals per corner (lateral force and camber moment, suspension damper stroke) will be measured with a WFT and a potentiometer and sent from the rig to the dSPACE system running the ACT logic over CANbus. The ACT motor controls response to the applied forces and moments with a translational movement adjusting the camber and toe angle of the wheel (Figure A2).

ACTIVE REAR AXLE SIMULATION AND LOAD GENERATION

Accurate load generation involves combining the recorded loads of a passive suspension vehicle with the response of a dynamic vehicle simulation (Figure 1). The reference data to generate the control signals for the virtual durability test rig, wheel center forces, moments and vertical displacement comes from the Ferrari test track, Fiorano. In this simulation each rigid wheel is actuated by six force channels and the possibility to activate a vertical displacement input to the rigid wheel. The rough road events

would also demonstrate the suitability of the existing vehicle model to reproduce the force amplitude and frequency conditions required.

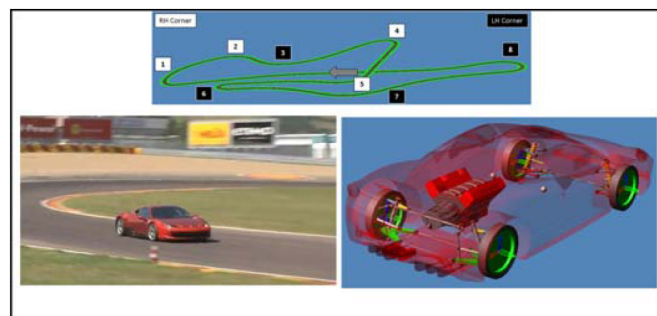


Figure 1. Ferrari Reference Track Fiorano and ADAMS Model on Virtual Durability Test rig

The virtual system components consisted of the full vehicle ADAMS model with a rigid wheel to accept measured road load from a passive suspension and the AMESim model of the electromechanical actuator.

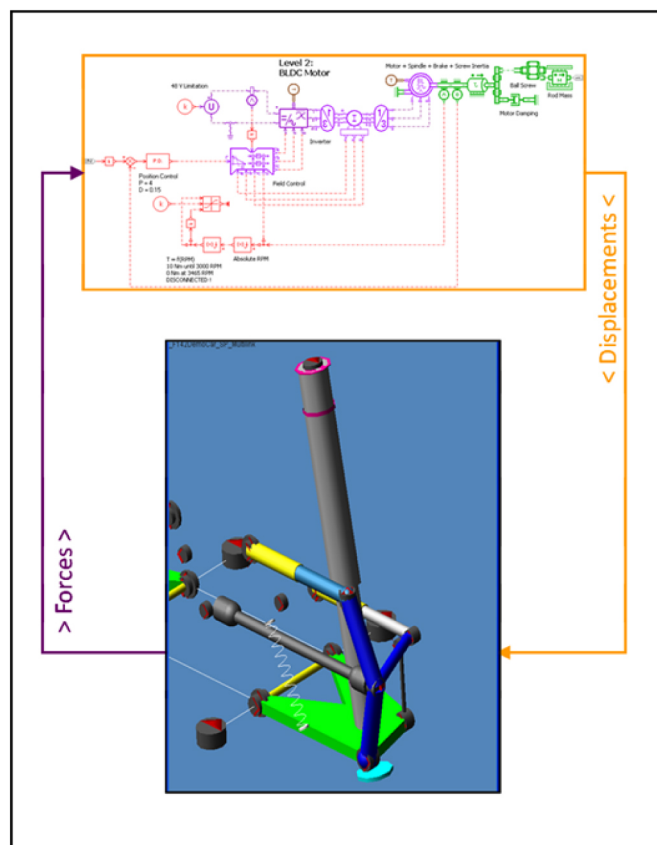


Figure 2. Active Rear Axle Simulation Communication between AMESim and ADAMS

The Adams model of the rear suspension has been adapted to work in cosimulation with the electromechanical AMESim model, the communication is the displacement

input from AMESim to ADAMS and force output from Adams to AMESim (Figure 2).

Through the simulation outputs we can obtain the wheel center forces and moments, rear left and right, which will be used as inputs for the desired data to the 329 road simulator. Additionally we obtain the actuator channels torque (Figure 3), displacement (Figure 4), current (Figure 5) and dissipation heat (Figure 6).

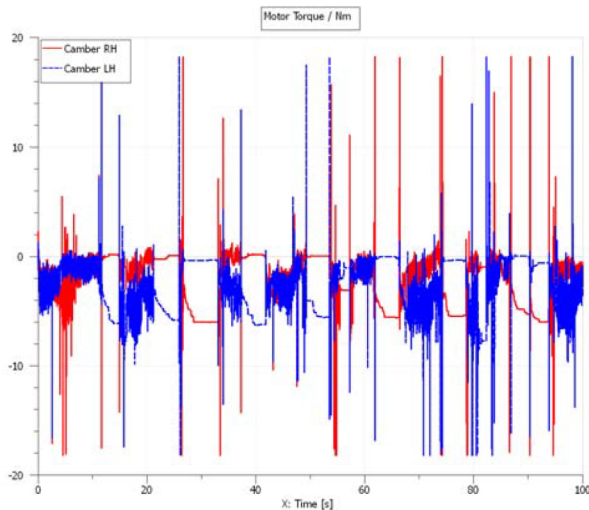


Figure 3. Active Rear Axle Durability Simulation on Reference Track: Camber Actuator Motor Torque

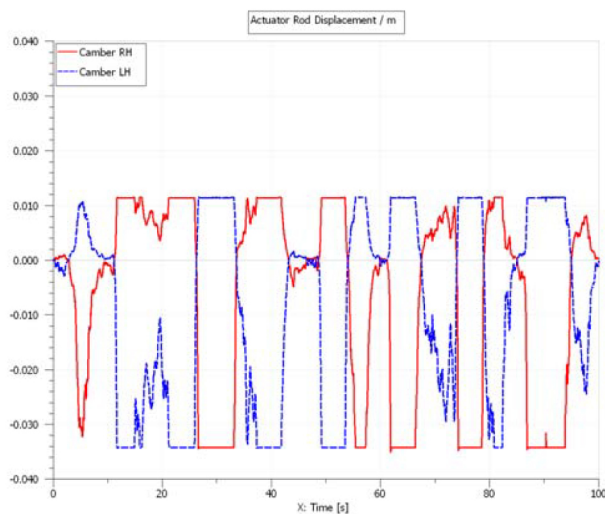


Figure 4. Active Rear Axle Durability Simulation on Reference Track: Camber Actuator Rod Displacement

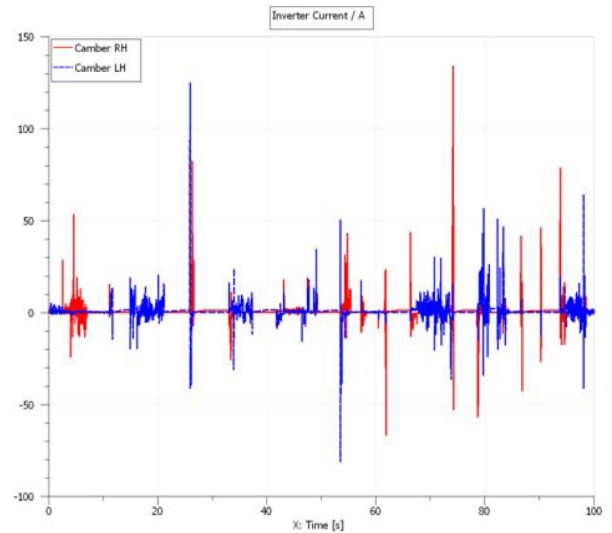


Figure 5. Active Rear Axle Durability Simulation on Reference Track: Camber Actuator Inverter Current

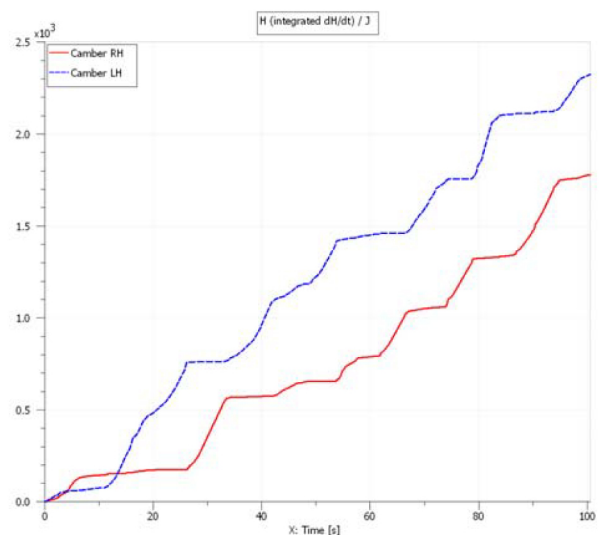


Figure 6. Active Rear Axle Durability Simulation on Reference Track: Camber Actuator Motor Dissipation Heat

ACTIVE SUSPENSION PERFORMANCE AND DURABILITY EVALUATION WITH HYBRID SIMULATION TECHNIQUES

Hybrid vehicle simulation methods combine the physical test specimen (active rear suspension) with a detailed complementary vehicle model, and the virtual road and driver inputs required to simulate the actual driving environment. Safety and security risk associated with operating prototypes on the track can also be avoided while developing the proper vehicle control.