Active Ride Simulations at Jaguar Land Rover Vehicle Dynamics using SIMPACK and MatSIM

An essential part of the vehicle dynamics development process is Computer Aided Engineering (CAE) simulation. The ability to simulate and predict vehicle performance is crucial in moving the development process forward and driving financial and environmental efficiencies. Today, vehicle suspensions have improved significantly from classic passive mechanical systems. Now highly sophisticated active suspensions have been developed which have been designed to overcome the natural performance constraints of classic passive suspensions. For successful virtual prototyping studies it has become essential that these active systems are accurately modelled. At Jaguar Land Rover Vehicle Dynamics we have been able to successfully integrate active control system models with highly detailed SIMPACK multi-body dynamics models for vehicle ride analysis using the MatSIM interface. This has provided a set of analysis capabilities which have significantly benefited the development process.

DUAL NATURE CHARACTER

At Jaguar Land Rover a major target of the Vehicle Dynamics development team is to ensure that optimum ride comfort is achieved without compromising steering or handling attributes. The vehicle dynamics are developed with much emphasis on achieving what has been described as a dual-nature character: exceptional levels of ride comfort with an engaging sporty character (Jaguar products) and exceptional levels of ride comfort with excellent and poised body control (Land Rover and Range Rover products).

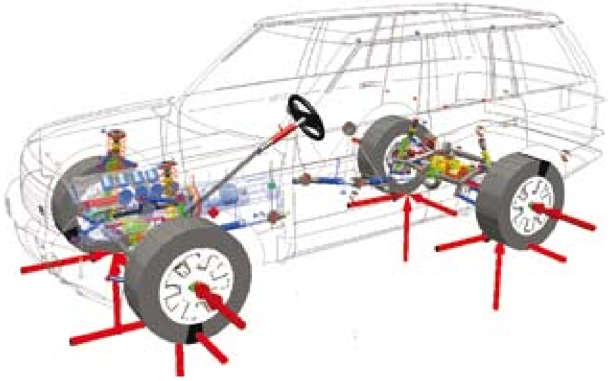


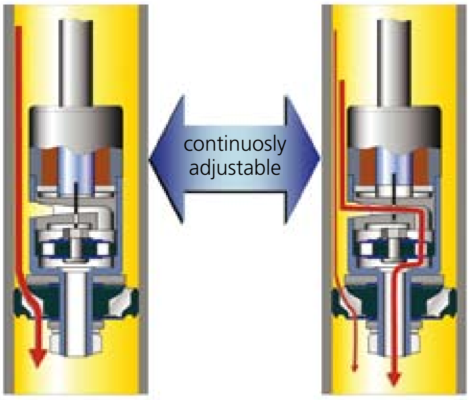
Fig. 1: Typical Jaguar Land Rover SIMPACK vehicle model

CONTINOUSLY VARIABLE DAMPING

To achieve this dual-nature character a number of technologies have been introduced. Active damping, such as Continuously Variable Damping (CVD) is one such technology. This technology is capable of providing a solution which overcomes the natural conflict between secondary ride comfort and body control, a conflict which is so often apparent in the performance of vehicles with typical passive spring-damper setups. This technology works by enabling intelligent adjustment in damper forcing based on vehicle sensor feedback and, where the primary driver controls are used (steering, brakes, throttle), a degree of pre-emptive behavior called "Feed-Forward". This is achieved by electronically adjusting a special slider-valve in the damper hardware which allows for greater or lesser flow of oil, thus providing a lower or higher damper forcing as per demands of the control system algorithm.

A major step in the vehicle dynamics development process has been our ability to integrate the CVD control system with our detailed SIMPACK based CAE multi-body dynamics models using the MatSIM interface. This has allowed us to perform active simulations and predict vehicle dynamics performance in an active state at the early virtual prototyping phases of the project lifecycle. This has supported us in better understanding the requirements of both hardware and software settings to achieve optimum vehicle dynamics performance.

Fig. 2: Jaguar XJ with CVD active control



slider closed — damper firm   slider open — damper soft

Fig. 3: CVD damper schematic

This active virtual prototyping capability has much potential in reducing the financial costs and increasing the environmental efficiency of the vehicle development process by reducing core prototype tuning activity. It must also be added that this capability can have a significant effect on the company's competitiveness in terms of maintaining and improving an already excellent level of vehicle dynamics attribute performance. This will naturally occur when simulation derived control system tuning parameters are provided to development engineers who, in turn, will benefit by beginning their tuning activities from a vehicle performance level much closer to desired vehicle targets as opposed to from somewhat nominal performance levels.

VEHICLE DYNAMICS RIDE MODELS IN SIMPACK

The multi-body dynamics models developed for vehicle dynamics ride analysis at Jaguar Land Rover are highly detailed. The suspensions are modeled with detailed compliances, and custom force elements have been developed for a number of key vehicle systems. These include user force elements for dampers, air springs and engine hydromounts. Bodies and components which are known to potentially affect vehicle ride comfort are modeled flexibly, using FEMBS to interface NASTRAN models. The foundation of these models has been based on the SIMPACK Automotive Database. Standard Automotive Database model templates have been used and some custom model templates have also been developed and added to a now growing library. This approach has formed a well structured and consistent model development process.

Full vehicle models have been developed by combining these model templates from the Automotive Database directory. Models are parameterized using Excel based parameter files. A customized Excel parameterization interface has allowed us to develop some very user friendly interfaces which enable non-expert SIMPACK users to complete basic model parameterization tasks.

"The foundation of these models has been based on the SIMPACK Automotive Database."

The models developed accurately predict vehicle ride performance and are used to support vehicle development from concept to final engineering sign-off phases of vehicle projects.

CVD CONTROL MODEL CODE EXPORT USING MATSIM

Two approaches have been adopted for control system integration with Vehicle Dynamics models at Jaguar Land Rover vehicle dynamics. For high-level initial studies, real-time vehicle models are used in the MATLAB® and Simulink® environments, which directly interface to control system models in the Simulink environment.

For detailed study of control systems interaction, particularly at higher frequencies, the control system models are integrated with high fidelity SIMPACK based multi-body dynamics models using the MatSIM interface.

To study vehicle behavior with CVD in simulations, the Chassis Electronics division has provided us with a Simulink model of the bespoke JLR controller. Initially this controller model has been configured in Simulink such that required vehicle sensors signals are setup as inputs. Similarly, the outputs of the controller were set to damper current demands. On the physical damper hardware, it is this current which alters the position of the solenoid valve, altering in turn the flow of the fluid within the damper and thus damper forcing.

Controller parameters which are required to be accessible for tuning purposes within the SIMPACK MatSIM environment have been defined within the Simulink Real-Time Workshop settings. Following this correct definition, the Simulink model has been exported using the Real-Time Workshop. This process generates a dynamically linked library file (.dll file) which has been imported using the MatSIM interface in SIMPACK and used as a SIMPACK Control Element.

The setup of the correct sensor input signals has been essential for the correct functioning of the controller in the SIMPACK models. These input signals have been defined in the "Sensors" section of the model "Control

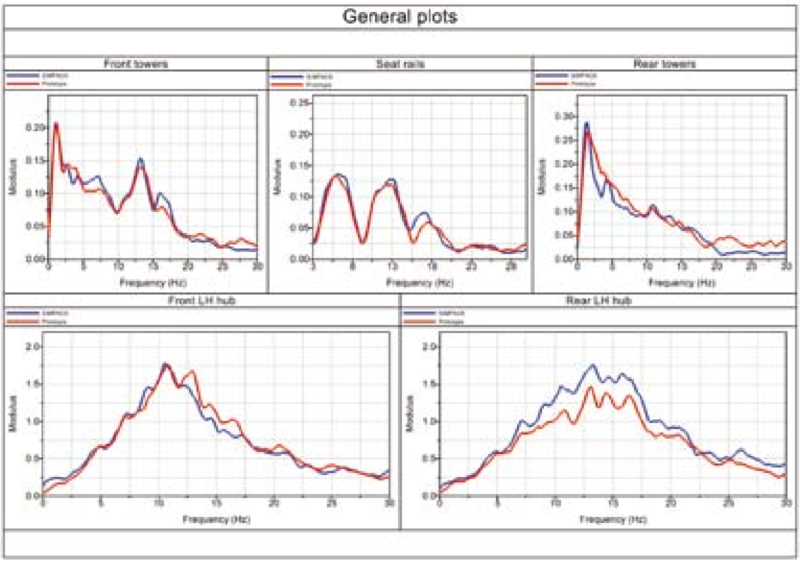


Fig. 4: Typical model correlation

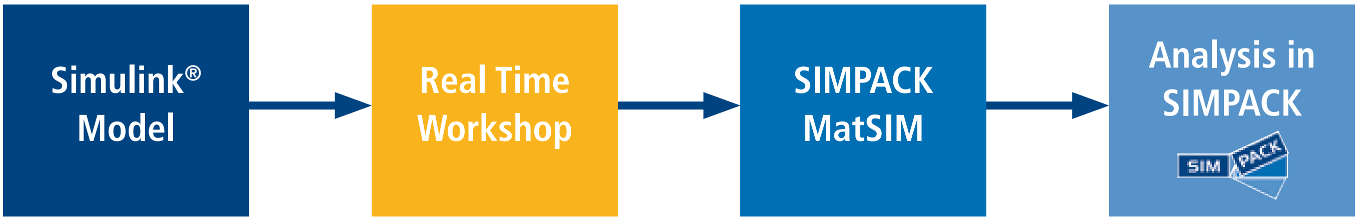


Fig. 5: Controller integration process

Loop" definition, and have been correlated to real vehicle data.

The control system parameters have also been parameterized using substitution variables in the MatSIM interface. This has been an important part of the development process as there are more than 500 parameters defining the controller's function. Many of these are control system maps which can be tuned in an Excel based tuning sheet. This tuning sheet has been modified to export a SIMPACK ".sys" file which defines the controller substitution variables. This approach has allowed us to complete basic CAE tuning activities and also to import controller tunes from actual vehicle prototype tuning. Thus, CAE feedback on the impact of tunes on vehicle dynamics attributes is provided.

To apply representative damper forces in the SIMPACK model, a 3D force-velocity-current map has been used. The damper hardware for a particular configuration has been measured at various current demands, providing a number of force-velocity curves. These force-velocity curves have been plotted against the current they have been measured at to form a 3D map. This 3D map essentially represents the forces available from the damper hardware. In SIMPACK this has been modeled as an array function. Function expressions have been used to apply a damping force, based upon this array function, current demand outputs from the controller, and damper velocity sensors. The dynamics of the response of the damper hardware have been modeled within blocks in the Simulink model, making for a robust 3D look-up approach in SIMPACK.

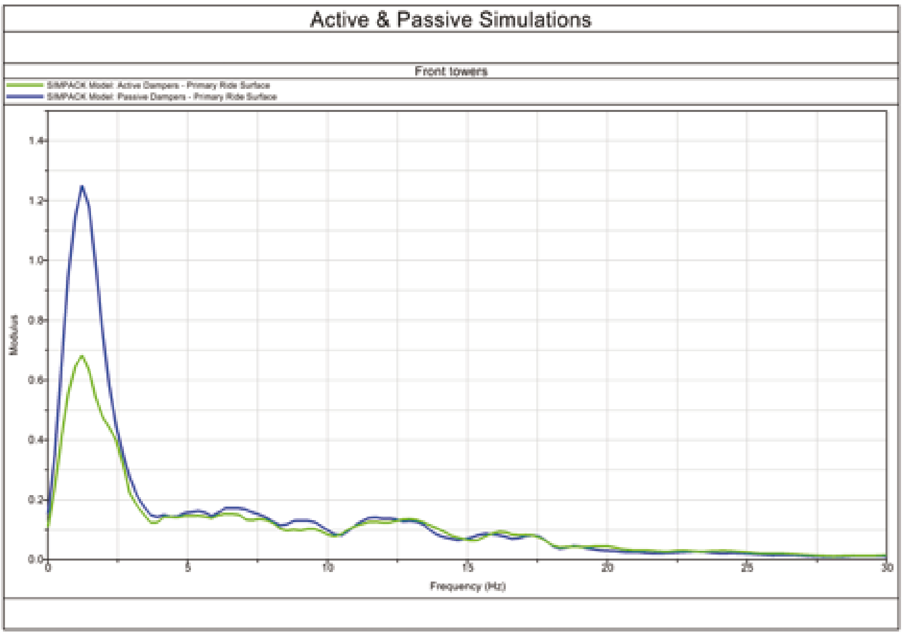


Fig. 6: Frequency response of simulation with and without CVD controller. Primary accelerations reduced (body control) without compromising secondary ride

RESULTS AND FUTURE WORK

This process has greatly supported us in understanding, at a very early stage in the project lifecycle, the system, hardware and software requirements necessary to achieve vehicle dynamics attribute targets. The CVD system capability is a function of both a hardware and software tune, though timing of the release of the hardware specification significantly precedes that of the software. Therefore the ability to predict the performance of particular hardware specification and software tunes together has been a key capability in ensuring that the correct hardware specification is supplied to suppliers, for optimum vehicle dynamics performance. Using this technique, we have had some excellent correlation with prototype vehicles in capturing improvements in vehicle response with the CVD controller.

A future aspiration is to develop this process further, combining multiple active control systems with real-time vehicle dynamics models. A significant future development will be the interfacing of active multi-body dynamics models with optimization codes for automated control system parameter tuning. This will no doubt have significant cost and environmental benefits and also support competitiveness of the vehicle dynamics attributes.

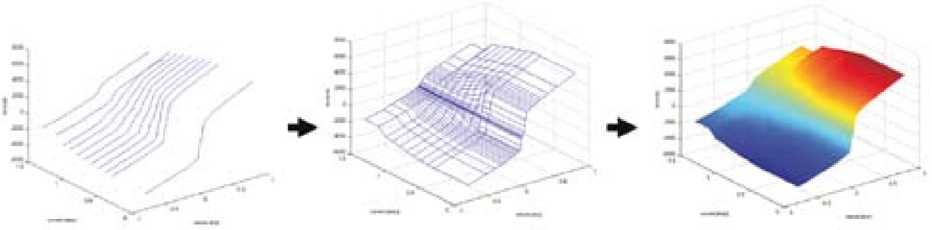


Fig. 7: 3D active damper characterization map