Honda Cuts Road Noise Using Hybrid Modeling and Simulation

Early Road Noise Identification by Combining Body Test Results and Suspension FE Model

ENGINEERING INNOVATION

In addition to its longstanding commercial success with vehicle models such as the Civic and Accord, Honda is systematically praised for its commitment to achieve high comfort, safety and performance standards. Among the factors that contribute to vehicle comfort, the control of road noise is of key importance. On several of its recently developed vehicles, Honda Motor Company succeeded in reducing road noise by using a new hybrid modeling approach. Together with LMS Engineering, Honda implemented a hybrid simulation process, capable of quickly and accurately modeling road noise at frequencies up to 300 Hertz. The approach consists of coupling a test-based model of the trimmed vehicle body with a Finite-Element (FE) model of the suspension system. The obtained hybrid full-vehicle model enables Honda to evaluate more suspension design alternatives earlier in the development, and to come up with more effective countermeasures for improved road noise performance.

Limitations of traditional approaches

Whether enjoying an enriched discussion, or a piece of light music during a tranquil ride, the comfort of a quiet interior makes a big difference. A potentially disturbing factor is road noise that propagates through the vehicle's mechanical structures and connections. As suspension assembly parts play a critical role in most of these propagation paths, it is very difficult to control and reduce road noise. The prediction of road noise levels prior to the physical prototype refinement stage has long been extremely challenging. The most common approach to early suspension design is to rely on rules of thumb derived from previous experience, such as the resonant frequency of the suspension links being above a given frequency, or the mount stiffness being within a certain range. The main problem with this approach is that there is no way to depend on these rules to predict whether a design modification will increase or reduce road noise.

Developing FE models of the entire trimmed body and all suspension components is another way to evaluate road noise performance. A disadvantage of using purely FE-based models of fully trimmed vehicles is the large modeling effort they require. The scale of this effort is hardly justifiable when the focus is limited to just the vehicle suspension. Another disadvantage of simulations using these FE models is that their prediction accuracy decreases as frequencies go up.

Hybrid Test-CAE approach increases speed and accuracy

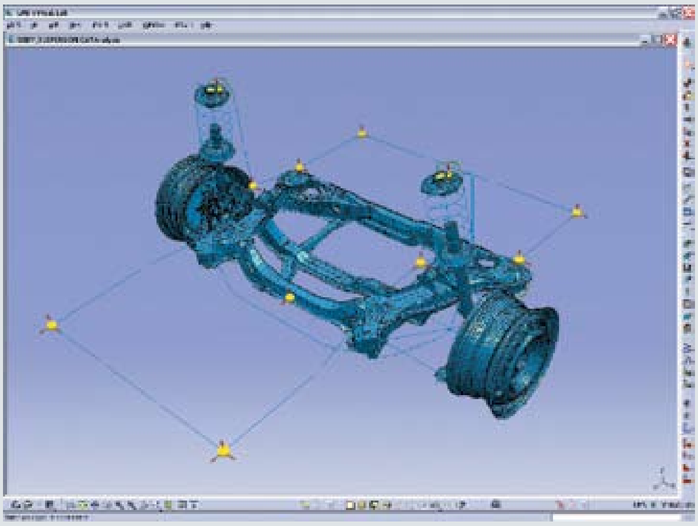
In order to evaluate its accuracy and usability, the hybrid modeling and simulation approach has been applied on an existing Honda model. The LMS Engineering Services team started by creating an FE-based model of the individual suspension system components, including the suspension links, shock absorber, subframe, etc. The models were validated through comparison with tests ran on their respective physical counterparts. Specific tests were performed on the shock absorber to identify its dynamic properties, such as bending modes, and effects resulting from stiffness and damping. The results of these tests were used to fine-tune the FE model of the shock absorber. Engineers succeeded in obtaining the model of the complete suspension model by coupling the various components and integrating the connections through the definition of bushing characteristics. The complete suspension model was validated using a dedicated test where the suspension was fixed to rigid boundaries. This setup ensures a realistic pre-load condition of all the bushings, which is crucial for the refinement of the linear bushing rates used in the FE model.

Then, the structural and vibro-acoustic FRFs of the car body were measured at all suspension-body attachment points. The advantage is that these measurements can be performed on any car body, for example a trimmed body prototype or a body of a previously released vehicle.

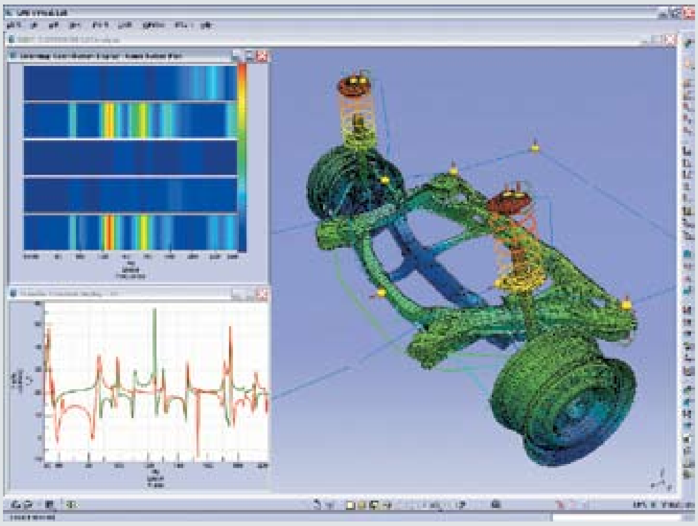
To connect the calculated FRFs of the suspension system and the measured FRFs of the car body, the FRF-Based Substructuring (FBS) method was used. This approach defines the FRFs of a combined assembly through the FRFs of its constituting components. The dynamic forces retrieved from operational vehicle tests were then applied through indirect force identification at the level of the wheel spindle. The model proved to be very accurate in simulating the measured vibration and road noise, throughout the entire frequency range of interest, being between 20 and 300 Hertz.

Empowering efficient design modifications

After building the full-vehicle model, LMS and Honda engineers evaluated the effect of various design modifications, for which



An FE suspension model and a test-derived body model combined into a hybrid FBS model.



Hybrid FBS models allow simulating transfer functions and noise level contributions early on.

physical test results on road noise were available. They implemented changes to the suspension system model by either modifying the geometry of the appropriate component FE model or by updating the coupling definition. They calculated the FRFs of the modified suspension system model and coupled the FRFs with those measured on the trimmed car body. By modifying the suspension FE model and recoupling it to the test-based vehicle body model, they systematically evaluated the road noise performance of a series of other modifications. One of the Honda engineers involved in the project commented, “The hybrid FBS model was found to be able to predict the road noise effect of large as well as more local modifications, such as changing the geometry of individual components or adding local masses. LMS engineers also used this model to calculate the structural and vibro-acoustic transfer functions, and compare them to the FRFs measured on the complete vehicle, in order to validate and further improve the model.”

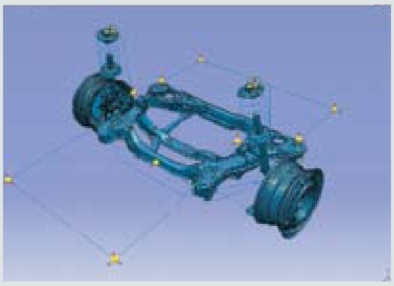
Further developments at LMS : NVH tire model

Indirect force identification at the wheel spindle is a very powerful procedure and is very often applied to investigate NVH (Noise, Vibration and Harshness) problems. One disadvantage however, is that the forces obtained depend to a certain extent on the type of tire used. In addition, when modifying the suspension model to predict modifications, it is possible that these forces change, and as a result reduce the accuracy of predictions. More recently, LMS has developed an improved method in which an experimental modal model of the tire is coupled to the wheel spindle. This model can be loaded by a forced displacement, which is directly related to the road surface geometry. This approach makes the model completely independent from the type of tire used and modifications made to the suspension system. The tire model can also be corrected to take into account the effect of tire rotation on its dynamic properties. At present, the use of this model is limited to noise evaluation on smooth roads, which are characterized by low displacements.

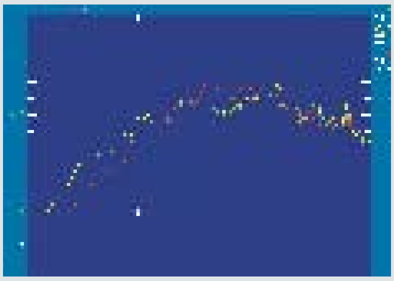
From validation to mainstream development

Compared to more traditional development sequences, the application of hybrid suspension/body modeling to reduce road noise is advantageous in more than one way. The Honda engineer concluded, “This hybrid modeling and simulation technique has already been used by Honda in a number of vehicle development programs. Integrating an FE suspension model in a test-derived body model enables Honda engineers to simulate a higher number of suspension design alterations at earlier stages in the development.
The road noise performance of the vehicle can be increased by gradually improving the geometry of the subframe and suspension parts, such as arms, wheels and knuckles. Implementing and assessing these numerous and profound changes would not be possible later on in the development, when a physical vehicle prototype becomes available. Modifying parts at this late stage is typically very expensive, time-consuming or simply not feasible.”Lab Noise and Vibration offers advanced

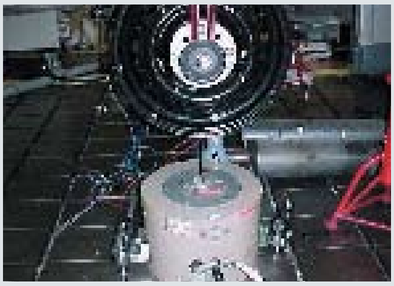
1 The car body model is modeled by measuring FRFs at all suspension-body attachment points.



2 FRF-Based Substructuring (FBS) allows reliably coupling test and simulation based models.



3 Hybrid FBS models are key in evaluating how design modifications impact road noise performance.



4 The new hybrid simulation approach was validated using FRF tests on a prototype vehicle.

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