Visteon's Approach to All-Wheel Drive Vehicle Dynamics Model Simulation and Correlation

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ABSTRACT

It is Visteon's belief that experimental correlation is essential in the development of analytical simulation models. A methodology for correlating an All-Wheel Drive (AWD) minivan, created with ADAMS/Pre is presented in this paper. The paper is developed in three parts. Presented first are detailed component and system level, static and dynamic tests, including tire tests that were performed for inputs to the model. Then, the static correlation of the model, in particular, the front and rear suspension kinematics and compliance correlation are presented. Finally the dynamic correlation of the model, for the constant radius test and the swept steer test, is discussed. The paper concludes with some observations on AWD modeling.

INTRODUCTION

Vehicle handling behavior is becoming increasingly important for today's discerning customers. Key segmentation characteristics are determined by quantitative and qualitative handling attributes. Also, the effort to predict the vehicle handling characteristics upfront in the design process is assuming an increasingly important role, with torque management to the wheels, and other important developments.

With vehicle dynamics refinement taking center stage, it has become increasingly accepted that use of well developed, Computer Aided Engineering (CAE) models present the best approach for upfront prediction of vehicle behavior. Meaningful results can be derived, and projections made, from the CAE model, only if the CAE results are correlated against real-world tests.

With this intent, Visteon chose an AWD minivan for its benchmarking exercise, and ADAMS/Pre, from Mechanical Dynamics Inc (MDI) as the Multi-body vehicle dynamics tool for the correlation project.

This paper presents the details of the methodology involved in component testing, system testing, and system correlation of the AWD vehicle.

COMPONENT TESTING

The weight, Center of Gravity (CG) and Inertia of the suspension components, the translational and rotational stiffness of bushings, damping rate of shock absorbers and struts, were measured. One of the key tests was the tire test, where Visteon employed the standard procedure for the high-mu test, and an innovative procedure for the low-mu tests. These tests were performed to fit a B-spline model for the lateral forces and Pacejka model for the longitudinal forces.

SYSTEM LEVEL TESTING

The coordinates of the vehicle suspension points were tested with a Coordinate Measuring Machine (CMM). The Kinematics and Compliance (K&C) testing machine

Figure 1: Kinematics and Compliance testing machine

(Figure 1) was used to obtain system level compliances, which are key elements of correlation. Vehicle level weights, CG and inertia were measured with the Vehicle Inertia Measurement Facility (VIMF) (Figure 2). Furthermore, the vehicle was instrumented and driven on a test track, to get the dynamic behavior in SAE standard tests, such the straight line acceleration, constant radius turn, high-G swept steer, etc. (Figure 3)

Figure 2: VIMF tester

Figure 3: Instrumentation for the AWD minivan Dynamic tests

VEHICLE MODELING

The Static Vehicle Characteristic - Iterate (SVCI) was performed to account for the inclusion of the unsprung masses in the VIMF test. Once the correct sprung mass, CG, and inertia were determined, the half-vehicle models in ADAMS/Pre were utilized for sub-system refinements.

The half-vehicle models were utilized to correlate the wheel rates (from the K&C tests), and the suspension rise. In this situation, the suspension rise for both the front and rear suspension is zero.

The Kinematics & Compliance machine is an MTS machine that takes the vehicle through vertical (jounce and rebound), roll and compliance motions. ADAMS/Pre has custom events that mimic these tests, which are very appropriate for correlation.

The wheel rate correlation for the front suspension was accomplished using the many tunable inputs available for the McPherson strut. The rear suspension does not have many tunable entities, as ADAMS/pre uses a beam-element based model for the leaf spring.

KINEMATICS & COMPLIANCE CORRELATION

It is best to work with a symmetric model since the ADAMS solver has difficulty converging to a solution (at least, in our case) with asymmetric models. The first metric Visteon focused on was toe curves for the front suspension (Figure 4). The test curves shows the hysteretic loop, as it accounts for the lost strain energy, while the ADAMS solution shows a single curve, as hysteretic loss was not modeled for this correlation project.

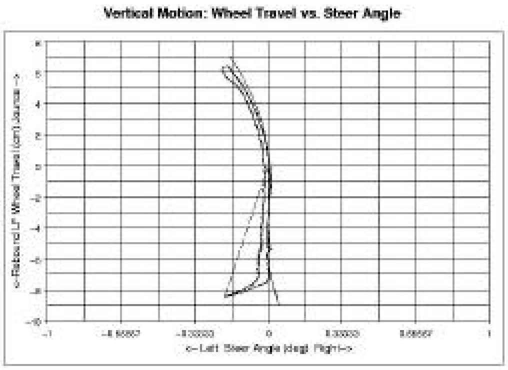
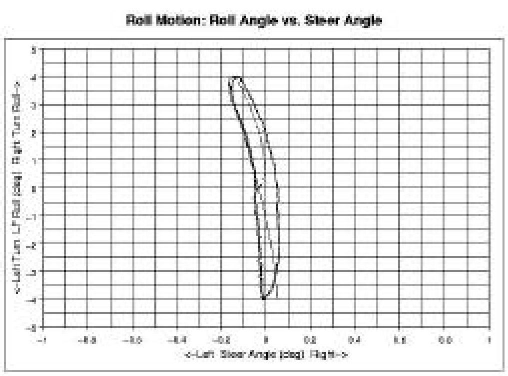


Figure 4: Toe curve correlation

The geometry features of the model were adjusted, to get both the slope and the inclination of the model to correlate with the test data.

The roll rate was correlated next (Figure 5). As can be seen, the model correlates very well with the test data, and stays in the hysteretic range. The Wheel rate



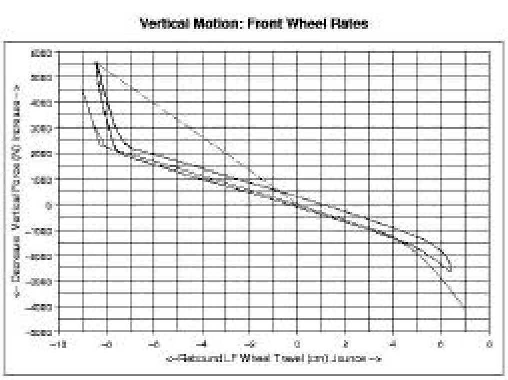


Figure 5: Roll rate correlation

Figure 6: Wheel Rate Correlation (Left Front)

correlation (Figure 6) for the front suspension was accomplished by paying attention to the McPherson strut. Closer inspection of the animation results offered good debugging clues, which led to the simulated slope for the front wheel rate having excellent correlation. The rebound bumper engagement is delayed some, and the rate is higher after jounce bumper engagement. The rear suspension (Figure 7) slope once again shows excellent correlation, even after jounce bumper engagement.

HUB COMPLIANCE

Since the toe, roll and wheel rate are correlated, Visteon had greater confidence in the model, and added hub compliance, for both the front and rear suspensions. Previously, the hubs were modeled as spherical joints. With this change, a variety of parameters for rear compliance (Figure 8), reflect greatly improved

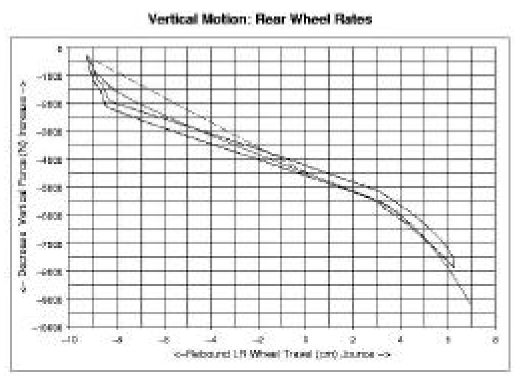


Figure 7: Wheel rate Correlation (Rear)

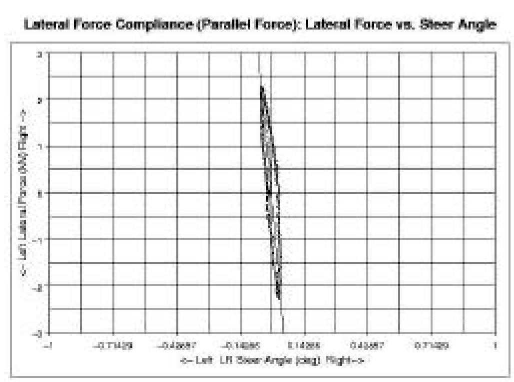


Figure 8: Lateral Compliance (Left Rear)

correlation. Improved correlation was observed in a variety of front suspension characteristics as well.

Thus, the kinematics & compliance correlation is complete, and dynamic correlation with the Dynamic Constant Radius Turn event and the Swept Steer event will be discussed in the next section.

DYNAMIC CONSTANT RADIUS TURN

The constant radius turn is an important event in fingerprinting. The turn radius is 61 meters, and for this event, a driver and passenger were added to the model. Based on the constant radius test information, an acceleration sensor was added to the model.

The slip angle vs. lateral acceleration curve (Figure 9) shows excellent correlation for the front suspension, even when the lateral acceleration reached 0.7g. Since the front suspension is a coil spring based McPherson, the various modeling parameters were better controlled during the correlation process. The rear De-Dion[1] suspension was modeled as a Hotchkiss suspension, and the leaf springs are modeled as Timoshenko beams. The rear leaf spring based suspension was not

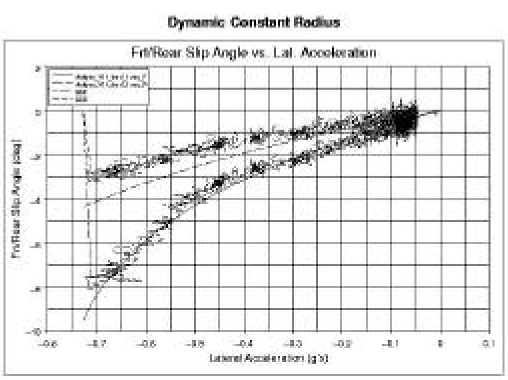


Figure 9: Front/rear Slip Angle Correlation

As tunable as the front, and it was more difficult to get the rear roll rates to correlate (Figure 10) as well as the front roll rates (Figure 5).

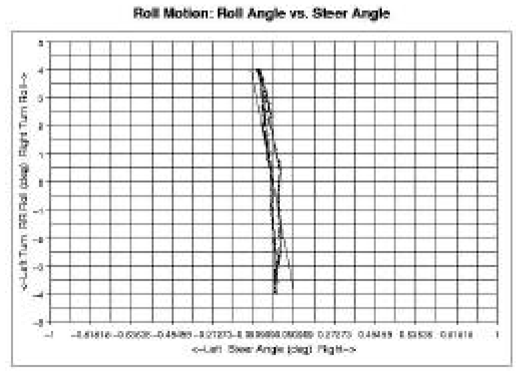


Figure 10: Roll rate correlation – Right Rear

As the summary of the Dynamic Constant Radius test result (Table 1) shows, the under steer gradient is well predicted by the model. For the rear suspension, the model cornering compliance is higher than the test. This results in the rear suspension having a higher slip angle in the simulation than the test, at higher lateral accelerations (Figure 9). This is also seen in the higher vehicle sideslip angle (Figure 11). The vehicle roll (Figure 12), exhibits good correlation, although at higher lateral accelerations, the model predicts a higher roll angle.

Metric	ADAMS/Pre	Test
Under steer Gradient (deg/g)	3.392 (left turn)	3.3 (average)

Table 1: Dynamic Constant Radius Test - Summary

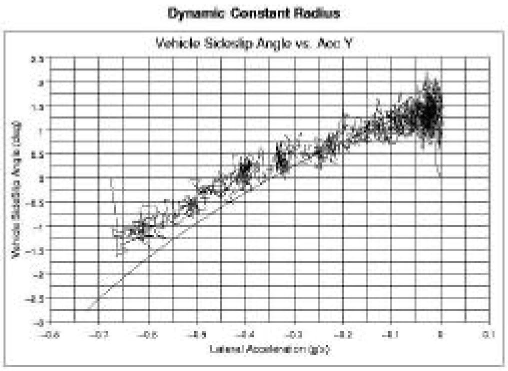


Figure 11: Sideslip Angle Correlation

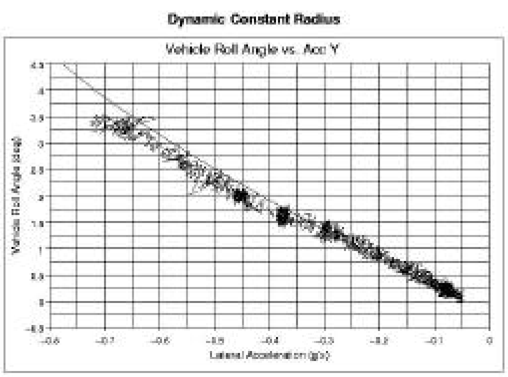


Figure 12: Vehicle roll angle correlation

SWEPT STEER TEST

The swept steer simulation was run at constant speed (100 kph), for a maximum lateral acceleration of 0.7g. The results (Figure 13) are remarkably similar to that of the constant radius test.

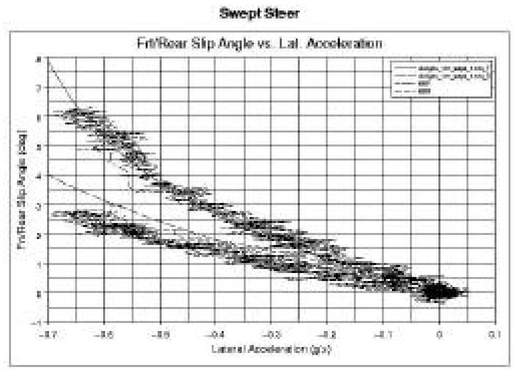


Figure 13: Front/Rear Slip Correlation

The front suspension slip angle correlates very well with the test results, even at higher g's. It is hypothesized that the rear suspension, on the other hand, deviates from the test, due to the higher rear suspension compliance discussed earlier. However, the rear slip correlation is better for the swept steer test than the constant radius test, in that the simulation results deviate far less for the swept steer test than for the constant radius test.

The sideslip angle and vehicle roll characteristics are similar to that of the constant radius test.

CONCLUSION

The coil spring McPherson front suspension correlation is excellent, and the leaf spring rear suspension correlates well. The leaf spring model has fewer parameters to experiment with than the coil spring model, and this explains the differences in suspension behavior, and the over-prediction of cornering compliances for the rear suspension. The tire model [2] could be another factor in the over-prediction of cornering compliances for both the front and rear suspension.

The ADAMS/Pre vehicle simulation procedure enables Visteon to develop high fidelity, well-correlated models. Visteon is working with MDI to incorporate the same features on ADAMS/Car as well. These models help Visteon predict vehicle handling characteristics upfront, and help us provide value added service to our customers.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Gillespie, Thomas, “Fundamentals of Vehicle Dynamics”

[2] Milliken, William F., and Milliken, Douglas L., “Race Car Vehicle Dynamics”.