Development & Validation of a Finite Element Model for the 1996 Dodge Neon Passenger Sedan

Background
A finite element (FE) model based on a 1996 Dodge Neon passenger sedan was developed through the process of reverse engineering at the National Crash Analysis Center (NCAC) of The George Washington University (GWU). This model was validated to the National Highway Traffic Safety Administration (NHTSA) frontal New Car Assessment Program (NCAP) test for the corresponding vehicle. This model was developed to support FHWA and efforts to improve highway and vehicle safety. This technical summary provides details on the important features of this FE model and its validation.

Modeling
A production 1996 Dodge Neon passenger sedan was purchased as the basis for the model. The reverse engineering process systematically disassembled the vehicle part by part. Each part was cataloged, scanned to define its geometry, measured for thicknesses, and classified by material type, all data entered into a computer file, and then meshed to create a computer representation for finite element modeling that reflected all of the structural and mechanical features in digital form.

The resulting FE vehicle model has 270,768 elements and does not include the interior components or restraint system. A representation of this model is shown in Figure 1. Parts were broken down into elements such that critical features were represented consistent with the implications of element size on simulation processing times.

The properties of the materials used to produce the vehicle parts were established or confirmed by testing specimens taken from the vehicle in the reverse engineering process. Material characterization followed accepted materials testing procedures using multiple samples. From the testing, strain rate values were determined and assigned to each element to allow the analysis of stress and strain behavior in crash simulations.

FIGURE 1 – FE model of the 1996 Dodge Neon passenger sedan

This set of elements was translated into an FE model by defining each as a shell, beam, or solid element in accordance with the requirements for using LS-DYNA software [1]. The result of these efforts was an FE model with the following characteristics:

- Number of Parts: 336
- Number of Nodes: 288,859
- Number of Shells: 2,852
- Number of Beams: 122
- Number of Solids: 267,786
- Number of Elements: 270,768

The modeling effort detailed all components of the vehicle. Figure 2 shows the details of the model for the unibody frame for this vehicle. The engine was not modeled in detail as simulation experience has found that it reacts as a large rigid mass in crashes. Interior elements of this vehicle were not initially modeled.
Validation

This model was validated by comparing the simulation of the NHTSA frontal wall impact test with the actual data from NCAP Test 2320 for a comparable vehicle [2].

After general verification of the model, efforts were initiated to simulate the NHTSA full-frontal impact test of the Neon as shown in Figure 3. The objective of the NHTSA full-frontal impact into a stationary barrier at 35 mph is to provide consumers a crashworthiness assessment of the vehicle structure and performance of the restraint system. The resulting data also allows for a detailed comparison to simulation of the test using the Neon FE model.

For this simulation, accelerometers were positioned in the same locations as the NHTSA NCAP test (Figure 4). The most commonly benchmarked accelerometers for NCAP performance are the left rear seat, right rear seat, engine top, and engine bottom. The left rear seat and right rear seat accelerometers are used to measure the deceleration response and velocity of the vehicle after impacting the rigid wall.

The FE model NCAP simulation was performed using the LS-DYNA non-linear, explicit finite element code. The FE vehicle model was run using LS-DYNA Code Version 970 on a single precision Itanium 2 platform. Total duration of the simulation was 150 milliseconds to capture the initial impact until the rebounding of the vehicle from the NCAP load cell wall. The approximate computation time to run 150 milliseconds using 4 processors on a single precision SGI workstation was 47 hours.

Table 1 provides specific data for key parameters of the FE model and the vehicle used in the NCAP test. It is easily noted that all were very similar. More information on the NHTSA’s NCAP test vehicle information like vehicle weight distribution, vehicle attitude, center of gravity (CG) location, and fuel tank capacity are published in the NHTSA’s report for Test 2320.

The overall global deformation pattern of the FE model was very similar in the side view to that of NCAP Test 2320 (Figure 5).
TABLE 1 – Comparison of parameters for FE model and vehicle used in the NCAP test

<table>
<thead>
<tr>
<th></th>
<th>FE Model</th>
<th>Test Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kgs)</td>
<td>1333</td>
<td>1354</td>
</tr>
<tr>
<td>Engine Type</td>
<td>2.0L I4</td>
<td>2.0L I4</td>
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<tr>
<td>Tire Size</td>
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</tr>
<tr>
<td>Attitude (as delivered)</td>
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<td>F – 660</td>
</tr>
<tr>
<td>Wheelbase (mm)</td>
<td>2648</td>
<td>2642</td>
</tr>
<tr>
<td>CG (mm)</td>
<td>1046</td>
<td>1022</td>
</tr>
</tbody>
</table>

FIGURE 5 – Comparison of the side view global deformation for NCAP test and simulation

The global response of the vehicle was further benchmarked against the NCAP test data by comparing the average acceleration and velocity responses from the rear seat cross member and engine top and bottom accelerometers.

The data from the accelerometers mounted on the left rear seat and right rear seat were averaged and compared to the accelerometer response from the test, showing good correlation (Figure 6). The seat cross member acceleration plot shows that the FE model closely tracks the test deceleration response up to about 60 ms, and shows a similar deceleration trend, but greater maximum deceleration at 70 ms after impact due to vehicle crush.

FIGURE 6 – Comparison of average acceleration for rear seat cross member

The comparison of the average velocity at the rear seat cross member shows that the FE model tracks the test response closely until about 60 ms (Figure 7). After 60 ms, the FE model slowed down more quickly compared to the test vehicle.

FIGURE 7 – Comparison of velocity for rear seat cross member

The global responses of the engine top and engine bottom accelerometers also track the response from the test vehicle as shown in Figures 8 and 9. In the engine top and bottom acceleration plots it is noted that the model shows less deceleration. This discrepancy is attributed to the front part of the engine cradle being softer and undergoing more crush relative to the physical test. The difference in the
engine bottom peak acceleration is not considered unreasonable.

Figure 10 shows the comparison of the total force exerted by the vehicle on the load cell wall between the simulation and test. The plots are generally similar but there is greater variation between 30 and 50 ms. This variation is believed to result from the simulated vehicle rebounding earlier than the test, as might be expected with a softer engine cradle.

Figure 11 shows the total vehicle displacement, which tracks closely in both the test and simulation over time. This is considered important as displacement is a critical metric that is less subject to acceleration noise.

Figure 12 shows the comparison of the force-displacement curves over the duration of the crash event. The cross plot of force and displacement shows similar behavior of the vehicle in the test and simulation.

Last, in Figure 13 the total energy plot shows the energy balance throughout the simulation. The total energy for the crash simulation is nearly constant. During initial stages of the simulation, the kinetic energy of the system is at a maximum and internal energy of system is at a minimum. As the simulation progresses, the kinetic energy decreases and internal energy increases, as would be expected. However,
the total energy is balanced and remains constant. Since the sliding energy and system damping energy are not significant relative to total energy, they are not shown on the plot.

The first version of the model was posted in 2001. This FE model was subsequently enhanced to include full functional capabilities of the suspension and steering subsystems. Periodic updates have also been made to the model as problems were discovered. The latest release was posted July 3, 2006.

Model Enhancements
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Summary & Conclusions
A finite element model of the 1996 Dodge Neon passenger car was created through reverse engineering. This vehicle was modeled to support NHTSA and FHWA research efforts. The modeling effort led to a detailed model that consisted of 270,768 elements. Later enhancements provided representation of the functions of the steering and suspension components.

The model was validated by comparison to images and data derived from the NHTSA NCAP Test 2320, which involved frontal impact into a rigid wall at 35 mph. The comparisons of data from the test and the model included:

- View of side and underside deformations,
- Acceleration and velocity changes for the rear seat cross member,
- Movement of the accelerometers on the top and bottom of the engine,
- Total forces over time,
- Displacement over time,
- Force displacement plots, and
- Total crash energy and energy balance.

Both the vehicle kinematics and the accelerometer output data were compared and the simulation results showed good correlation with the physical test results.

The FE model was found to be stable in full frontal flat rigid wall simulations. The model was also run at 25, 30, 35, and 40 mph to ensure stability.

References
4. Reid, J. and Marzougui, D., “Improved Truck Model for Roadside Safety Simulation, Part I – Structural Modeling,” In Transportation Re-


For More Information
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