Development & Validation of a Finite Element Model for the 1997 Geo Metro Passenger Sedan

Background
A finite element (FE) model based on a 1997 Geo Metro 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 NHTSA occupant risk and vehicle compatibility studies and Federal Highway Administration (FHWA) crash research and barrier development efforts. This technical summary provides details on the important features of this FE model and its validation.

Modeling
A production 1997 Geo Metro 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 thickness, and classified by material type. The components were meshed to define elements, the material characteristics and connectivity to other elements were established, and element types were defined to create a computer representation or finite element model of the vehicle that reflected all of the structural and mechanical features in digital form.

The resulting FE vehicle model has 193,200 elements and does not include the interior components or restraint system. This detailed FE model was constructed to include full functional capabilities of the suspension and steering subsystems. 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 in the vehicle parts were established or confirmed by testing specimens taken from the vehicle in the reverse engineering process. Material characterization followed accepted material testing procedures using multiple samples. The material testing determined the strain rate values that would allow the analysis of stress and strain behavior in crash simulations.

FIGURE 1 – FE Model of the 1997 Geo Metro 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: 230
- Number of Nodes: 200,348
- Number of Shells: 191,980
- Number of Beams: 2
- Number of Solids: 1,209
- Number of Elements: 193,200

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 behaves as a large rigid mass in crashes. Interior elements of this vehicle were not initially modeled.
Validation

After general verification of the model using LS-DYNA, efforts were initiated to simulate the crash of the Geo Metro FE model as in the NHTSA full-frontal impact test (Figure 3). The objective of the 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 data that results from such tests also allows comparisons to various metrics that indicate the validity of the simulation model. For this vehicle, frontal wall impact test data from NCAP Test 2239 was used for comparison [2].

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 NCAP test vehicle, including weight distribution, attitude, center of gravity (CG) location, and fuel tank capacity are published in the NHTSA’s report for Test 2239.

<table>
<thead>
<tr>
<th>Location</th>
<th>Node</th>
<th>FE Model</th>
<th>Test Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Seat</td>
<td>2200235</td>
<td>1997</td>
<td>1995</td>
</tr>
<tr>
<td>Right Seat</td>
<td>2200227</td>
<td>1.3L I4</td>
<td>1.3L I4</td>
</tr>
<tr>
<td>Engine Top</td>
<td>2200246</td>
<td>1.3L I4</td>
<td>1.3L I4</td>
</tr>
<tr>
<td>Engine Bottom</td>
<td>2200252</td>
<td>P155/80R13</td>
<td>P155/80R13</td>
</tr>
<tr>
<td>Attitude (as delivered)</td>
<td>F – 640</td>
<td>F – 646</td>
<td></td>
</tr>
<tr>
<td>R – 655</td>
<td>R – 661</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheelbase (mm)</td>
<td>2325</td>
<td>2375</td>
<td></td>
</tr>
<tr>
<td>CG (mm)</td>
<td>884</td>
<td>1117</td>
<td></td>
</tr>
</tbody>
</table>
There was some variation in the vehicle features data as the test vehicle was a sedan and the modeled vehicle a hatchback.

The overall global deformation pattern of the FE model was very similar in the side view to that of NCAP Test 2239 (Figure 5).

The global response of the vehicle was further benchmarked against the NCAP test data by comparing the 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 average velocity in the simulation tracked the average velocity in the test although the simulation showed a slightly higher velocity (Figure 7).

The global response of the engine top and engine bottom accelerometers also tracked the response from the test vehicle, as shown in Figures 8 and 9. There is, however, a lower peak acceleration that is attributed to the front part of the engine cradle being softer than the test vehicle and hence undergoing more crush relative to the physical test.
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 reasonably similar except around 40 milliseconds where the wall force from the simulation tends to drop off faster than in the test. This may be indicating that the FE model is rebounding earlier than the vehicle in the test.

Figure 11 compares the force-displacement curves. The cross plot of force and displacement shows similar behavior of the vehicle in the test and simulation.

Figure 12 shows the energy balance during the simulation. The total energy for the crash simulation is nearly constant. As expected, the kinetic energy of the system is translated to internal energy. The total energy is balanced and remains relatively constant. The sliding energy and system damping energy were not significant relative to the total energy, so they were not plotted.

Summary & Conclusions
An FE model of the 1997 Geo Metro passenger sedan was created by reverse engineering a production vehicle. This vehicle was modeled to support a wide range of NHTSA and FHWA research efforts. The modeling effort led to a detailed model that consisted of 193,200 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 2239, which involved frontal impact into a rigid wall at 35 mph. 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

For More Information
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