COMPARATIVE ANALYSIS OF A VEHICLE IMPACTING A RIGID BARRIER, AN OFFSET DEFORMABLE BARRIER, AND A RIGID POLE

Seong-Woo Hong, Chung-Kyu Park, Pradeep Mohan, Richard M. Morgan, and Cing-Dao Kan
The George Washington University

Kisu Lee, Shinhee Park, and Hanil Bae
Hyundai-Kia Motors

ABSTRACT

The objective of this paper is to show a timeline of the dynamic response of the structure of a current passenger vehicle impacting (1) a full-frontal rigid barrier, (2) an offset frontal deformable barrier, and (3) a center pole. A finite element model was used for the study with a time step of 1 microsecond. The behavior of the frame rail is shown at 20-msec increments. It was found that the passenger vehicle managed the full-frontal crash and 40% offset frontal crash well by absorbing crash energy in the side rails. In the center rigid pole impact, the pole missed the side rails, a vehicle's primary energy-absorbing component, and caused undesirable occupant compartment intrusion. The occupants in the *no-rail* type of crash would benefit by a transverse connection (or coupling) to the frame rails.

Keywords: FRONTAL IMPACTS, FINITE ELEMENT METHOD, CRUSH ZONES, VALIDATION

The Insurance Institute for Highway Safety (IIHS) analyzed real-world data to show that narrow objects contribute to death and injury in frontal crashes (Albelaez, 2006). They conducted a series of pole tests using passenger cars that had previously been rated *Good* in the 40% frontal offset test. Passenger cars were impacted into a rigid pole with a 25.4-cm-diameter at 64-kph (Hong, 2008). In most of the tests, the frame rails—a vehicle's primary energy-absorbing component—missed and did not engage the pole. Sullivan et al. (2008) studied all frontal crashes in the USA, and found this *no-rail* crash to be the deadliest in terms of fatalities/number of crashes. She found the narrow and *no-rail* groups are 12% of all frontal crashes and 19% of fatalities and serious injuries in frontal crashes.

Figure 1 shows a comparison of intrusions of the laboratory tests of the full-frontal rigid barrier, the 40% frontal offset, and the frontal center pole of the 2001 Ford Taurus. In the pole impact, the right toepan and brake pedal extend far into the occupant compartment. The analysis will show how and when this unwarranted intrusion happened.

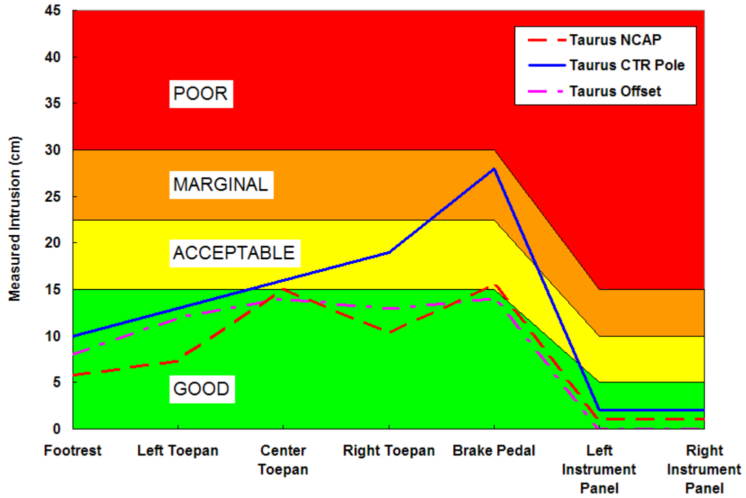

Figure 1 - Comparison of Ford Taurus Intrusions in Full-Frontal, Center Pole, and Frontal Offset Tests

METHODS

The FHWA/NHTSA National Crash Analysis Center (NCAC) built a finite element model (FEM) of the model year 2001 Ford Taurus. The FEM consists of 778 parts and 1,057,113 elements. The model simulated the (1) full frontal rigid barrier test at 56-kph, (2) frontal offset (40%) deformable barrier test at 64-kph, and (3) frontal center pole test at 64-kph. Major energy-absorbing components (rail, rail-upper, sub-frame and bumper) of the finite element model of the Taurus are shown in Figure 2. The existing engine, hood, fenders, wheels, and so on are transparent in Figure 2 and in later figures.

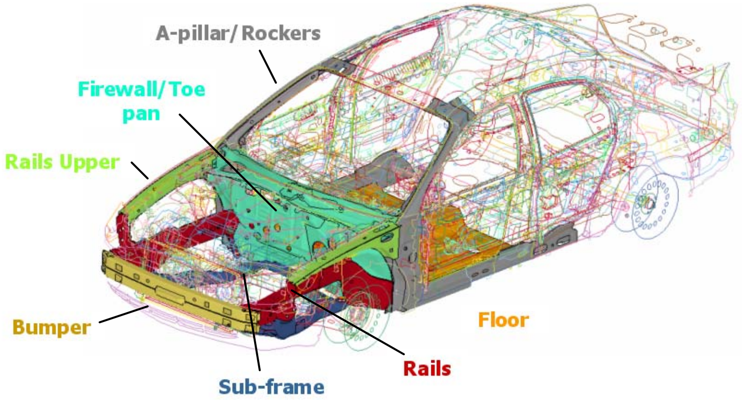

Figure 2 - Main Structural Components of 2001 Ford Taurus (Other Major Parts were Made See-Through)

Using the FEM model of the Taurus, each of the three crashes was examined in 20-msec increments starting from the initial contact of the vehicle with the object impacted. During each 20-msec time step, the frame rails are viewed from beneath the vehicle.

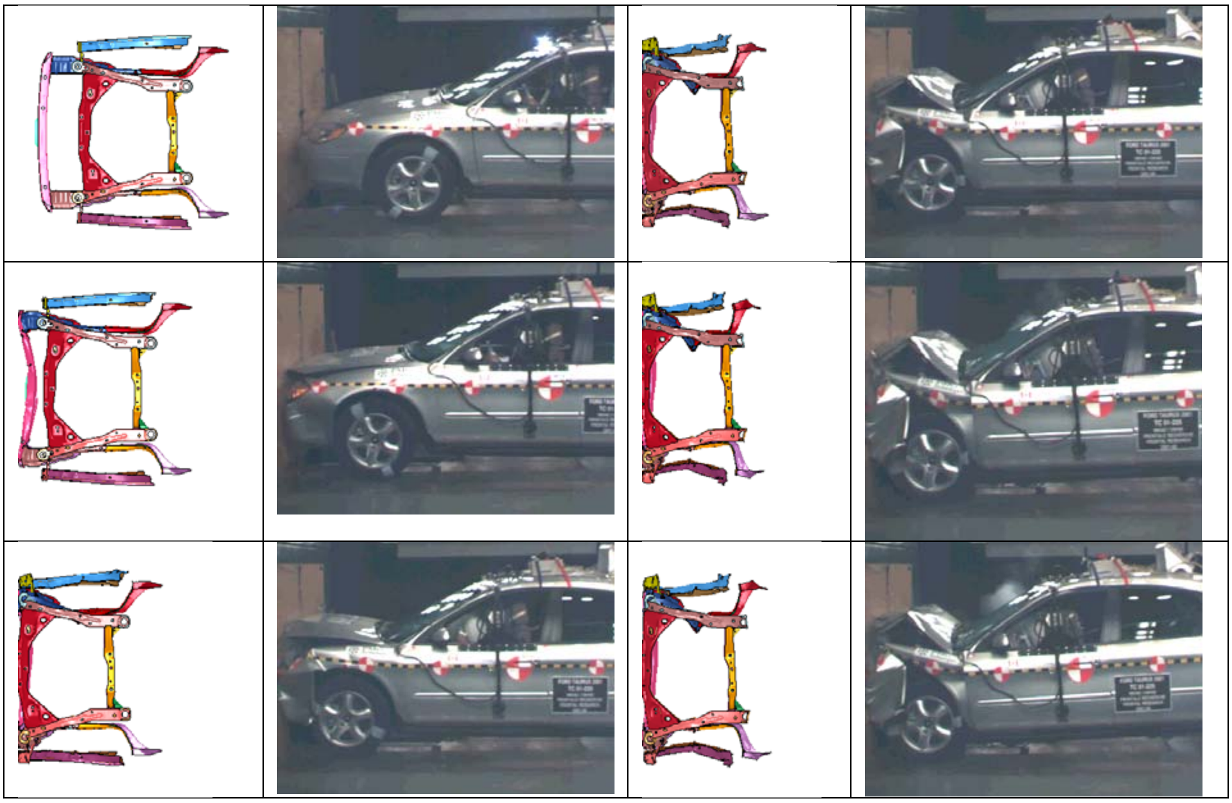

Figure 3 –Comparison of Computational (underneath vehicle view) and Experimental Dynamics for the Full-Engagement Rigid Barrier (0 to 100-msec in 20-msec interval)

DATA SOURCES

The National Highway Traffic Safety Administration (NHTSA) crashed a Ford Taurus into a rigid barrier. The IIHS crashed a Ford Taurus in a 40% offset frontal barrier test and in a center pole impact. The full-engagement-frontal rigid barrier test is shown in Figure 3. Looking at the bottom view, the side rails absorb the energy well. The bumper bar does not bend, and the sub-frame crushes very little. In the rigid barrier test, the side rails crush and absorb a good deal of energy.

The 40% offset deformable barrier test is shown in Figure 4. Looking at the bottom view, the left-side rail absorbs energy well. The bumper bar bends a little, and the sub-frame begins to crush. In the 40% offset test, the left-side rail crushes and absorbs a good deal of energy.

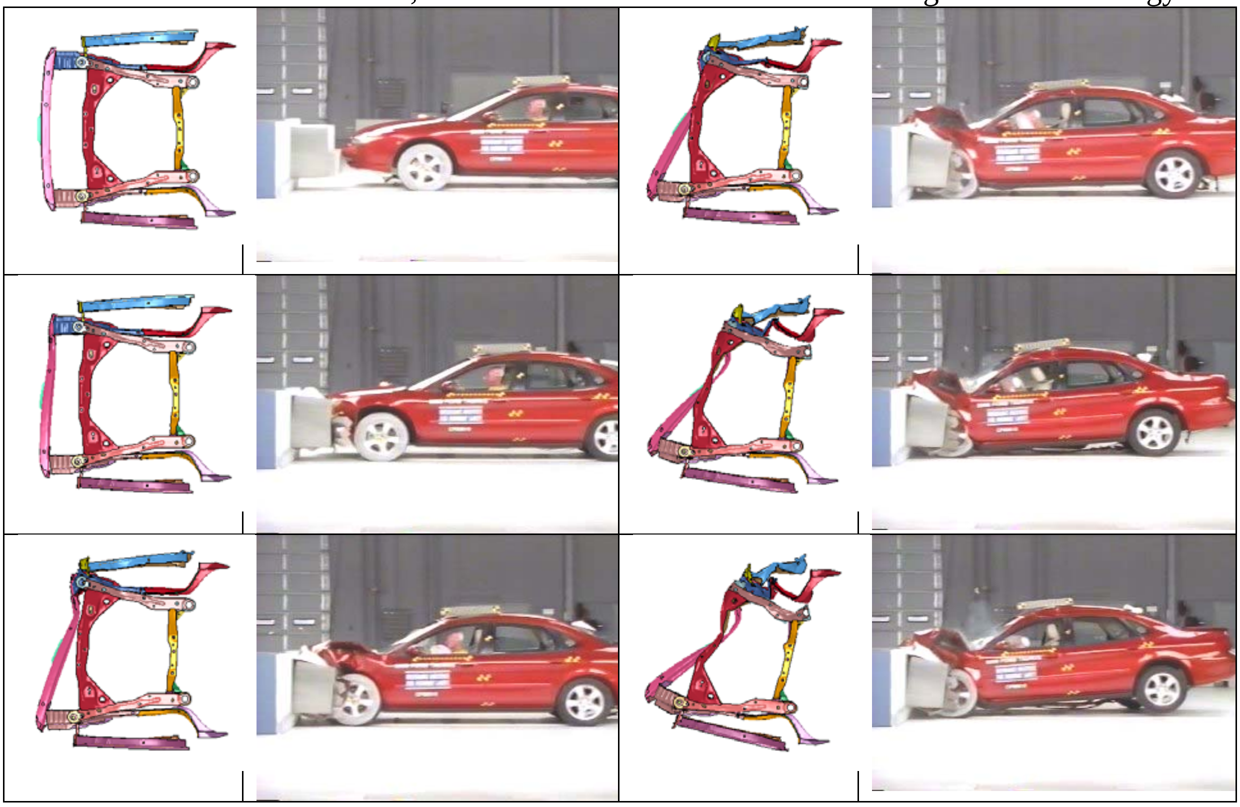

Figure 4 –Comparison of Computational (underneath vehicle view) and Experimental Dynamics for the 40% Offset Deformable Barrier (0 to 100-msec in 20-msec interval)

The center pole test is shown in Figure 5. Looking at the bottom view, it is shown that the pole thrusts between the side rails. The bumper bar bends greatly. The sub-frame begins to crush greatly. In the center pole test, the side rails—able to absorb a large amount of energy—are ineffective. For brevity, the large occupant compartment intrusion and the high crash dummy readings of this *no-rail* crash are not presented in detail. For the *no-rail* impact, judged the most dangerous frontal crash by Sullivan, one prudent countermeasure is to make a transverse connection (coupling) that transfers the load to the frame rails about 40 – 60-msec.

CONCLUSION

A finite element analysis of a passenger car was performed for a (1) full-frontal impact, (2) 40% frontal offset impact, and (3) a center rigid pole impact. A graphical comparison illustrated the side rails crushed greatly in the full-frontal and the 40% offset crash. In the center pole impact, the pole misses the frame rails. While not shown in detail because of space limitation, compartment intrusion and dummy readings were high in this *no-rail* type of crash. A transverse component is needed to transfer load to the frame rails in the 40 – 60-msec time period.

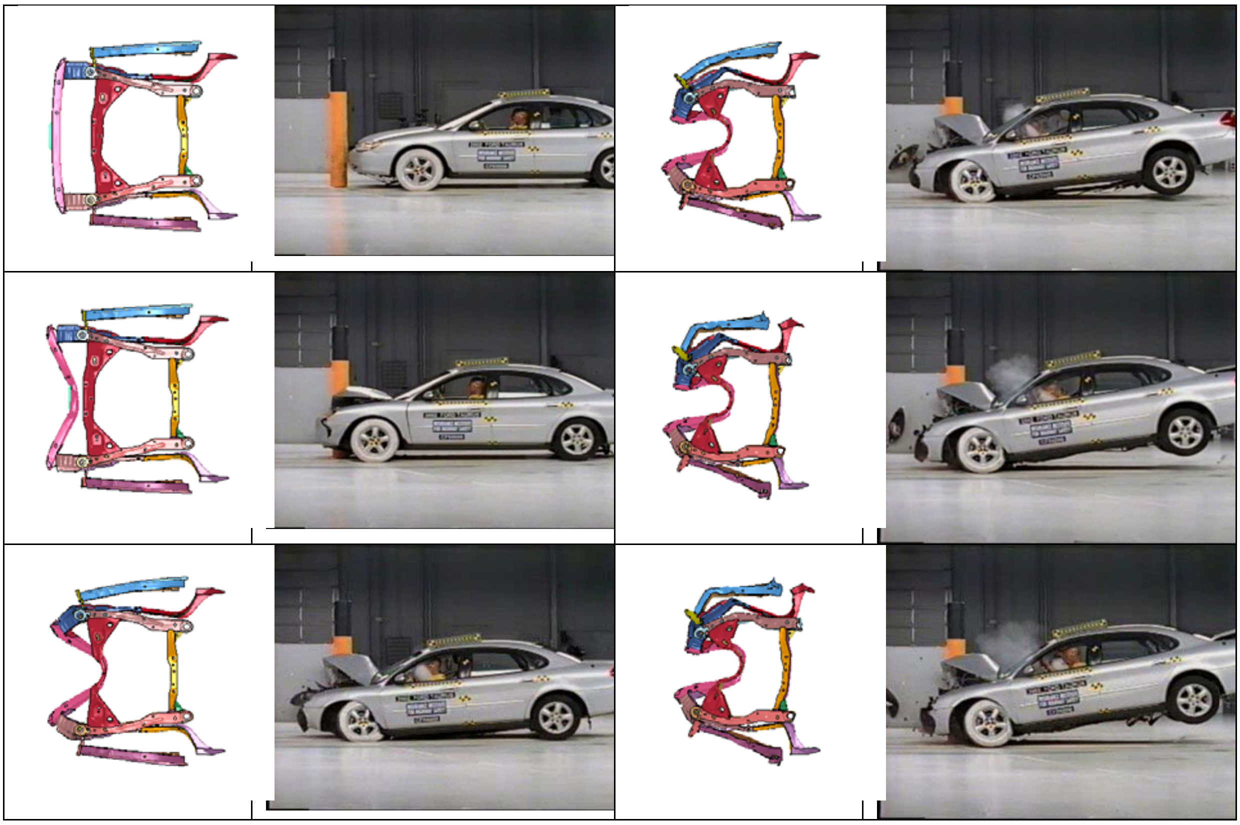

Figure 5 –Comparison of Computational (underneath vehicle view) and Experimental Dynamics for the Center Pole (0 to 100-msec in 20-msec interval)

REFERENCES

Arbelaez, R.A., Aylor, D., Nolan J.M., Braitman, K.A. and Baker, B.C., "Crash Modes and Injury Patterns in Real World Narrow Object Frontal Crashes," IRCOBI Conference, Madrid, Spain, September 2006, 333 - 336.

FHWA/NHTSA National Crash Analysis Center Finite Element Model Archive (http://www.ncac.gwu.edu/vml/models.html).

Hong, S-W., Park, C-K., Mohan, P., Morgan, R.M., Kan, C-D., Lee, K., Park, S., and Bae, H., "A Study of the IIHS Frontal Pole Impact Test," SAE World Congress, SAE Paper No. 2008-01-0507, Detroit, Michigan, 2008.

NHTSA Vehicle Test Database (http://www-nrd.nhtsa.dot.gov/database/nrd-11/veh_db.html), NHTSA.

Sullivan, K., Henry, S., and Laituri, T. R., "A Frontal Taxonomy for USA Field Data," SAE World Congress, SAE Paper No. 2008-01-0526, Detroit, Michigan, 2008.