CHILD SIDE IMPACTS: SIMULATION OF MID-SIZED SEDAN IN SIDE IMPACT TO DESCRIBE CRASH ENVIRONMENT

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ABSRACT

A structural and kinematic evaluation of a representative mid-size sedan subjected to lateral impacts with various crash partners is described. A detailed evaluation of the exterior crush, interior intrusion, and vehicle motion is provided using measurements and data from computational simulation. The mid-size sedan is struck by partner vehicles that cover a range of vehicle sizes common in the US fleet. These include a side impact with a small car, a mid-size car, a LTV, and a MDB. Specific focus on the rear seating row is included to develop impact data that will help to describe the crash environment for rear seated child occupants.

This portion of the project builds upon previous work that has examined mid-size sedans involved in real world side impacts and those tested in lateral impacts with regulatory and consumer metric test conditions. The long term goal of this project series is to create a detailed understanding of children involved in side impacts. This report provides insight into the range of possible intrusion patterns for various impact partners that may contact a rear seated child occupant. Future evaluations will then utilize this data to understand the sensitivity of injury for restrained children exposed to these crash conditions.

INTRODUCTION

A cooperative effort by multiple research organizations is being conducted in order to examine child occupants involved in vehicle side impacts. The overall goal of this study is to develop an understanding of how children are being injured in side impacts and what can be done to reduce the risk. This process involves an examination of three fundamental factors of side impacts. These include the behavior of vehicles involved in side impact, the risk and mechanism of injury to children, and the role of countermeasures. A comprehensive understanding of these three factors is needed prior to proposing and testing improvements that might reduce injury.

As described by previous research of child involved accidents (Arbogast, 2004), child injury in side impact is sensitive to compartment intrusion. Case reviews of accidents with injured children often cite intruding door panels, trim, or other interior components as the injury source. The most common injuries for the children in the age group of 1-3 years old for these crashes are injuries to the head and lower extremities. Farside or middle seated occupants are also subject to intrusion injury, but may be more susceptible to vehicle motion as is seen with farside adult occupants.

In the interest of producing data to support the development of a laboratory test condition that can assess child injuries from side impacts, it was decided that the early stages of the overall research project would focus on rear row crash conditions in side impacts. Children within the United States in the target age group, 1-3 years old, are shown to have high occupancy rates for rear seating rows. These can include nearside, farside, or middle seated children. They are also most commonly transported in sedans. Details are being sought to describe rear row interior intrusion and external crush patterns, and overall vehicle kinematics for various severities of side impacts for sedans. As stated in previous documentation surrounding this project (Tamborra, 2005), the assessment will broaden to other vehicle types at a later point.

SIDE IMPACT STUDIES

A previous report on the topic of child side impacts illustrated the exterior crush patterns for mid-size sedans involved in field accidents and compared these with results of similar vehicles subjected to current side impact test methods (Tamborra, 2005). Additional summaries of similar studies conducted by many researchers were also considered as supporting data for the overall project. Similarities and differences between real world sedans involved in side impacts and those tested against various MDBs were described. The purpose of this comparison was to start looking for crash conditions for rear seated restrained child occupants involved in side impacts.

In order to complement the data that was obtained from crash investigations and vehicle tests, computer simulation of side impacts is employed in this report. The use of simulation for this stage of the project offers insight into the specific interaction of structural members between the struck car and the striking vehicles. The simulation output can be examined in detail over the entire impact event by using the computational data output and graphics.

With conventional testing it is difficult to illustrate the exact manner in which vehicle structures interact with each other during the impact event. Transient crash data is available through the use of sensors and film analysis, and improvements in miniaturized cameras have expanded visual coverage. Engineers can use accelerometer timing, sensor contacts, and pre-crash geometric measures to understand how the vehicles may interact, but only in limited cases with external fascia removed, can one see exactly which parts are contacting. It remains a challenge in physical crash testing to be fully aware of component interaction and the effect this has on either the structural response of the vehicle or the injury measures captured by the ATDs.

Computer crash simulation has the benefit of being fully illustrated with component interaction clearly shown. In addition, data output for specific areas of interest is neither limited by physical constraints of instrumentation, nor is it influenced by the dynamic event itself, i.e. damaged sensors, rotating axis, channel noise. Researchers are able to view the exact deformation and interaction of any part that has been included in the model.

Simulation is however limited by how well the models are able to predict actual crash outcomes. Complex simulations involving occupants and vehicle interiors, as well as those with complex material models or contacts can be difficult to rely on. Simulation has been in use for several decades though and common practices employed by analysts can help to improve the simulation output.

The most appropriate way to employ simulation is to use it in tandem with physical testing and to draw out whatever information adds value to the research. For the purpose of this study the simulation will be used to examine the potential structural response of a mid-size sedan impacted by several vehicles using a controlled setup and velocity. The models are able to help understand the potential crash environment that the rear seated child may be subjected to under these conditions. The cause and effect relationship between the crash partner and the crash outcome is illustrated by the simulation output.

INJURY AND SIDE IMPACT

ATD injury response is often sensitive to minute variations in the exterior loading of a vehicle and the resulting impact between dummy and the interior. This is especially true in side impacts where the dummy is in close proximity to the impacting partner. Crash engineers can optimize ATD injury measures by balancing the localized loads that are exerted on the dummy. This often includes shoulder leads, pelvic blocks, arm rest positioning, and more recently airbag interaction. The interior trim that interacts with the ATD in side impact is mounted onto stiffer underlying structural components such as the b-pillar and door. Impacts that might put the dummy and countermeasures out of balance or alignment may subject the dummy to unintended load paths. Although considerable margins of safety can be built intro the side impact load paths, deviations can occur due to the influence of the impacting partner.

When considering children restrained in the rear seating row of vehicles, the range of body position is diverse and depends on the type of restraint. Children in child seats may be perched higher and more forward than those seated on bolsters in seatbelts. Differences in head or chest locations can vary for children just a few years of age apart and all of these may differ from adults. It is therefore important to determine the structural response of a vehicle for a range of impacting partners in order to determine an expected boundary of structural deformation. Vehicle reinforcements optimized for specific crash inputs can then be exercised in a variety of impacts and an overall crush and kinematics profile can then be considered for an eventual subsystem test. By looking beyond singular crash events there should be opportunity to develop a robust test methodology that will help to assess injury for a broad range of impacts.

METHODS

This report covers the side impact of a mid-size sedan by multiple partner vehicles. These include a small sedan, a mid-size sedan, a LTV, and a MDB. The baseline crash condition is the US side NCAP test methodology using the NHTSA FMVSS-214 moving deformable barrier. The alignment of the barrier to the sedan and the input speeds are controlled for each impact. This process was selected in order to keep several variables common to help facilitate comparison.

The selection of impacting partners gives a satisfactory representation of current fleet vehicles for the United States. The spread in mass and the variation in build provide insight into the effects these have on the structural response of the struck car. Descriptions of the variation in front end construction for the four impacting partners is provided and insight into the cause and effect relationship is shown for how front end construction influences struck vehicle deformation.

The mid-size sedan was modeled with two forward facing child restraints installed in the rear outboard seating positions of the second row. These are models that are currently under development and will be used in future assessments with child ATD models. They were attached to the vehicle model using belt and tethers and are placed in outboard seating positions. The models were not included in the contact of the struck vehicle since the definition of the materials is incomplete. They are instead included to illustrate the kinematics of the child restraints in side impact to help to begin understanding the different challenges that a near and farside seated child may face. The child restraints were weighted to include the mass of a child seated on the restraint and should give an approximate description of how the seat moves during a side impact.

SIDE IMPACT TEST AND OUTPUT

The test mode used in this study is based on the US Side NCAP test procedure. The Taurus struck car will be impacted in the side by the four impacting vehicles using positioning and velocity values prescribed by the side NCAP procedure. The three bullet vehicles align themselves relative to the MDB by placing the vehicle longitudinal centerline at the MDB longitudinal centerline.

The following output is recorded for each simulation.

- Exterior maximum and residual crush along the length of the vehicle at four vertical heights
- Interior maximum and residual intrusion along the length of the vehicle at four heights
- Vehicle kinematics measured at various locations
- Interior trim shape and profile for rear seating rows

MODEL DESCRIPTIONS

Four different classes of vehicles are represented with finite element models. A brief description of each model is included for reference. Each model has been in existence for several years except for the Taurus model which is a pre-release version. All models were developed by the FHWA/NHTSA National Crash Analysis Center at The George Washington University under funding from the Department of Transportation. Many of the models are publicly available for use in safety research. Figure 1 provides an illustration of the four vehicles used as striking models and Table 1 provides a brief summary on model mass and size.

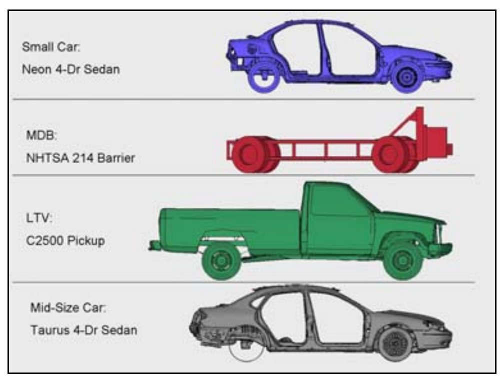

Figure 1. Striking vehicle finite element models.

Table 1.
Finite Element Model Summary

Models	# Elms	Mass
Taurus (Struck)	876k	1462kg
Taurus (Striking)	505k	1476kg
Neon (Reduced)	200k	1242kg
C2500	18.6k	2015kg
214 Barrier	57k	1368kg
Vanguard CRS	19k	19kg

Small Car

The small car vehicle class is represented by a 1997 Dodge Neon four door sedan. A finite element model of this vehicle was created by the NCAC Vehicle Modeling Lab and is publicly available for use in safety research. The vehicle model contains a complete representation of the Neon's body-in-white, mechanical drivetrain, and chassis. Rudimentary interior parts are available, but were not considered for use in the vehicle as a striking partner.

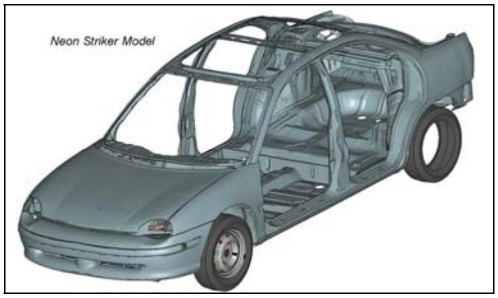

Figure 2. Dodge Neon Small Car FEA Model (Reduced Striker Version).

A reduced model was created from the detailed model in order to save simulation resources. Unnecessary components from the model were removed if they were deemed to be insignificant for the frontal impact of the Neon into the side of the Taurus. Adjustments to the vehicle mass were made in order to preserve the Neon's inertial properties.

Mid-Size Car

The mid-size vehicle class for this project is represented by a 2001 Ford Taurus four-door sedan. This vehicle served as both the baseline struck vehicle and as a striking vehicle. The Taurus model is an early version of the latest NCAC Vehicle Modeling Lab reverse engineering project. This model is a highly detailed recreation of a production Taurus sedan that features fully detailed structural BIW, interior components, drivetrain components, and suspension systems.

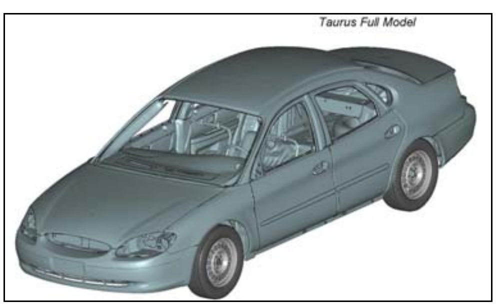

Figure 3. Ford Taurus Mid-Size Sedan FEA Model (Full Version).

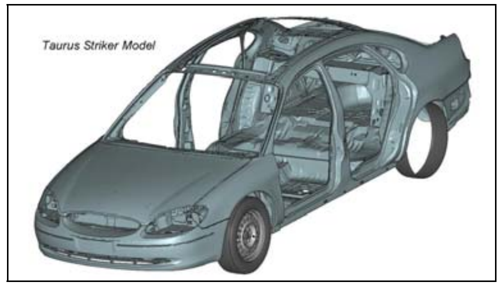

Figure 4. Ford Taurus Mid-Size Sedan FEA Model (Reduced Striker Version).

The striking model for the Taurus underwent a similar reduction process as the Neon in order to help reduce simulation time. Removal of rear components and rigidizing certain parts helped to reduce the runtime while having a minimal effect on the frontal performance of the Taurus as a bullet vehicle.

The baseline struck vehicle of the Taurus had several parts removed that were considered insignificant to a side impact vehicle. These included certain engine bay components and front passenger compartment interior components. This effort again helped to reduce the computational time while minimizing the affect on simulation output.

LTV

The LTV category is represented by a Chevrolet C2500 pickup truck developed at the NCAC Vehicle Modeling Lab. This vehicle model has been in use for nearly 10 years by researchers studying roadside hardware safety. The truck model features a detailed front end and suspension with a reduced representation of the rear pickup bed and passenger cabin.

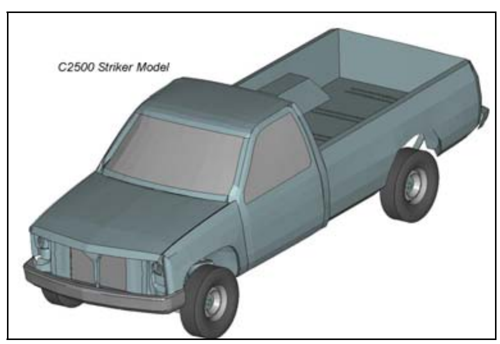

Figure 5. Chevrolet C2500 Full-Size Pickup FEA Model.

Moving Deformable Barrier (MDB)

The NCAC MDB barrier model was used for the program to represent the NHTSA specified FMVSS-214 impact barrier. The finite element model of the 214 barrier is fully compliant with the design specifications outlined in the federal register although current efforts are underway to improve the material modeling for the deformable honeycomb elements.

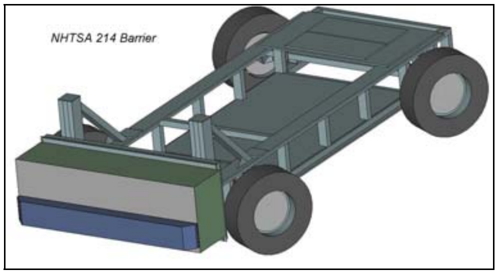

Figure 6. NCAC 214-Barrier MIDB FEA Model.

Child Restraint

The struck vehicle Taurus is modeled with two forward facing Evenflo Vanguard child restraints installed in the outboard rear seating positions. The Vanguard CRS was reverse engineered in the NCAC Vehicle Modeling Lab and is starting to be used in several child safety research projects. This child seat is a representative example of convertible child seats and features most of the common features including LATCH straps, side wings, top-tether, movable feet, and a one-piece molded shell.

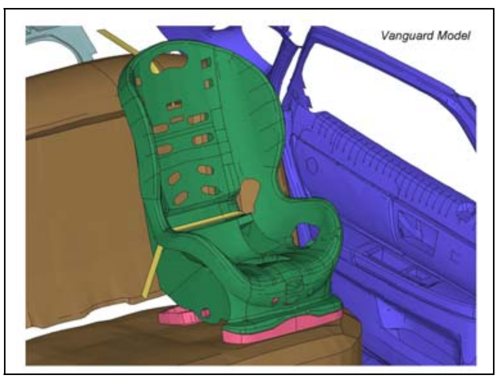

Figure 7. Evenflo Vanguard CRS FEA Model installed forward facing.

The CRS is installed in the two outboard rear seating positions for the Taurus rear bench seat. The child seats were installed assuming a vehicle belt installation. Actual child restraints were installed into a Taurus with measurements taken to approximate the location of the CRS. This location is different in the Taurus than a LATCH installed CRS since the Taurus lower LATCH anchors are shifted slightly inboard. The child seats were attached to the Taurus model using a lap belt routed through the forward facing belt guides and a top-tether strap attached to the upper anchor on the Taurus rear shelf. This is not an exact simulation of a real installation since the Taurus features three-point belts in the outboard locations. Future simulations will improve the modeling of the belt system to include the upper shoulder belt as sled testing with three point belts has revealed that the movement of the CRS is affected by the shoulder belt depending on load direction.

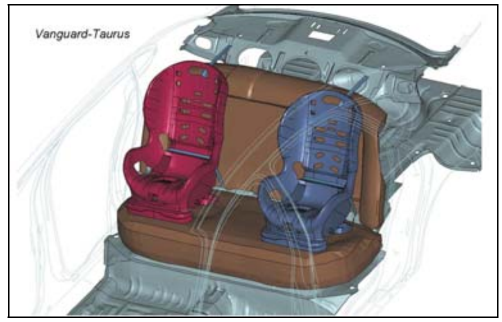

Figure 8. Twin Vanguard CRS models in Taurus second row.

DIMENSIONAL COMPARISON

The following series of figures illustrate the dimensions of the struck Taurus and the striking vehicles. Emphasis is placed on underlying structural components that affect performance in the side impact simulations. Illustrations of external sheet metal or fascia show the difference that can exist between components that are often included in external vehicle measurements, but have been shown to have minimal affect on the actual impact.

Struck Taurus Dimensions

Structural dimensions of the Taurus and Vanguard child restraint are provided in Figures 9 and 10. An illustration of the relative position of side impact countermeasures relative to the location of the child restraint is provided in Figure 11.

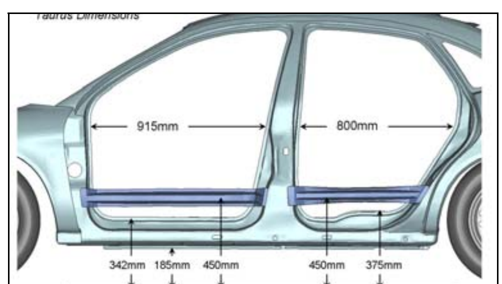

Figure 9. Taurus structural dimensions.

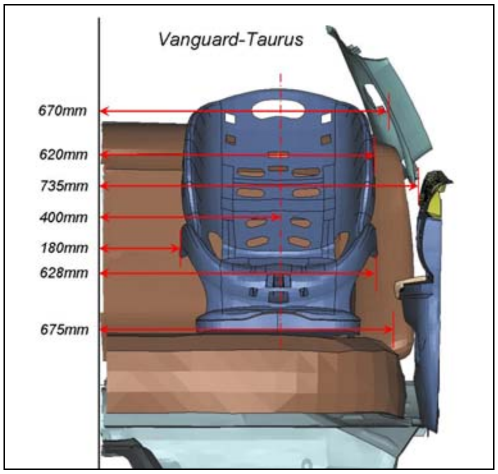

Figure 10. Vanguard/Taurus internal dimensions.

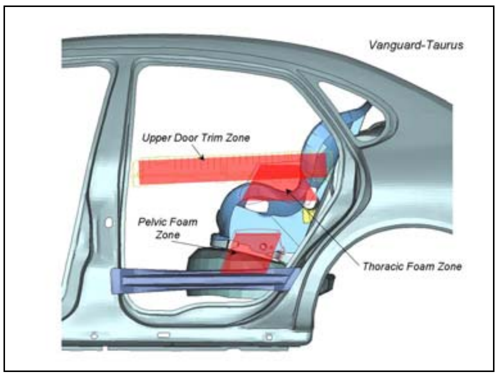

Figure 11. Vanguard/Taurus side impact occupant countermeasure overlap.

The reference system used for measuring external crush and internal intrusion is illustrated in Figure 12 and 13. This system is based on the US side NCAP protocol for pre and post crash test measurements. The system measures crush and intrusion at five levels, rocker, SID H-Point, mid-door, windowsill, and roof. The spacing along the longitudinal axis is 150mm with the origin located approximately 440mm rearward of the front axle centerline.

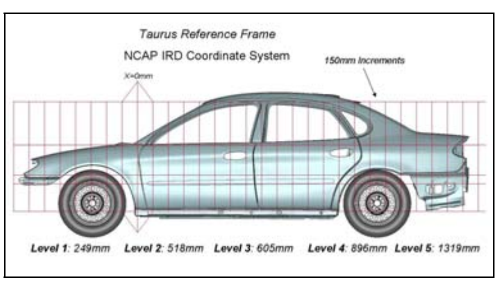

Figure 12. NCAP IRD Coordinate System for measuring external crush.

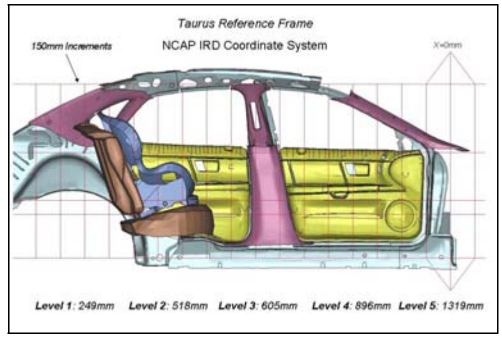

Figure 13. NCAP IRD Coordinate System for measuring internal intrusion.

Striking Vehicle Dimensions

Figures 14-27 illustrate the dimensions for the striking vehicles used to impact the Taurus. Dimensions of external fascia and underlying structural components are provided. An illustration that compares the relative size of the actual vehicles to the MDB is also given in order to facilitate later discussions of the impact results.

Differences between the structural designs of the four vehicle types are illustrated in the images. The front structural bumper of the Neon and Taurus are narrower in width and height than their outer fascia. This is different from the C2500 whose structural bumper is the outer surface. The differences between the design of the MDB and the structural components of the vehicles are also illustrated. Previous research by many organizations has highlighted this, but these illustrations should provide useful detail on several specific examples.

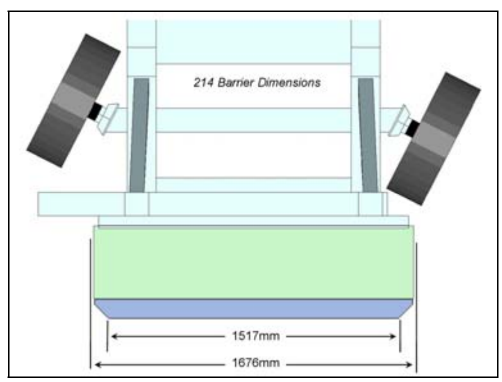

Figure 14. NHTSA 214-MDB dimensions.

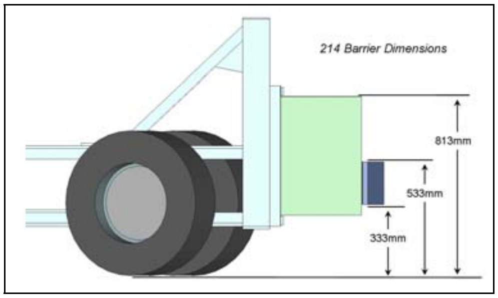

Figure 15. NHTSA 214-MDB dimensions.

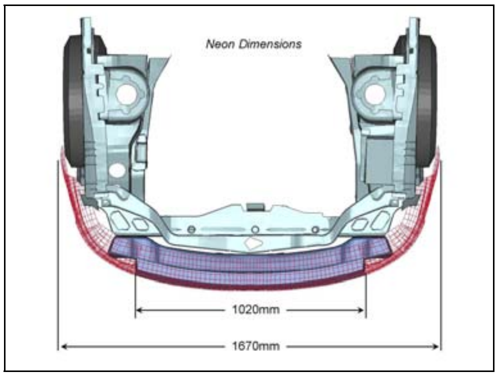

Figure 16. Neon structural dimensions.

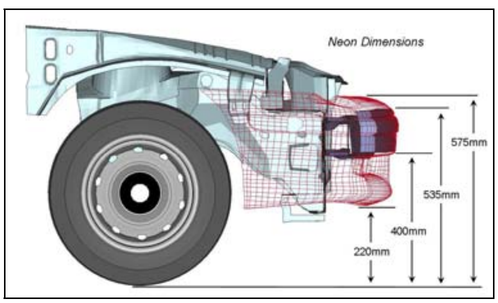

Figure 17. Neon structural dimensions.

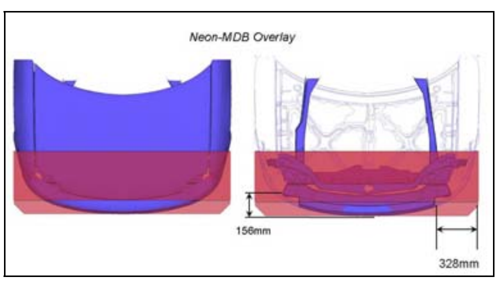

Figure 18. Neon-MDB dimension comparison.

Figure 19. Neon-MDB dimension comparison.

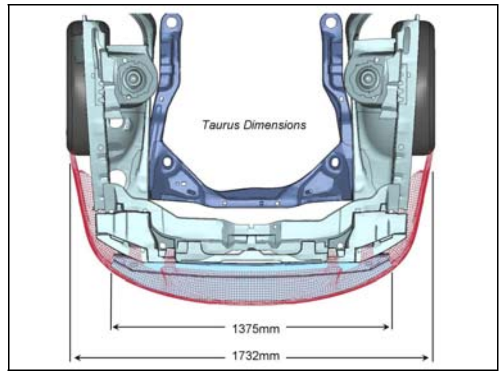

Figure 20. Taurus structural dimensions.

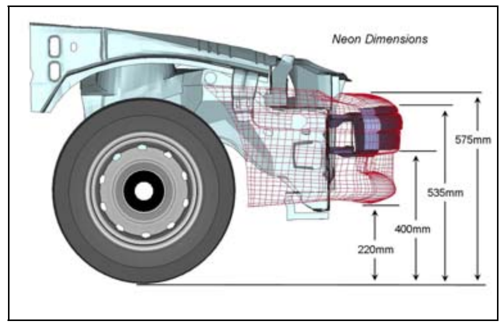

Figure 21. Taurus structural dimensions.

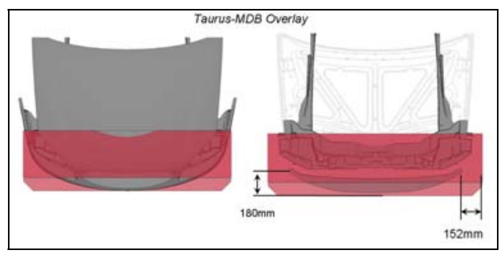

Figure 22. Taurus-MDB dimension comparison.

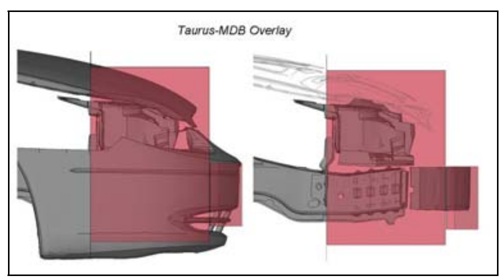

Figure 23. Taurus-MDB dimension comparison.

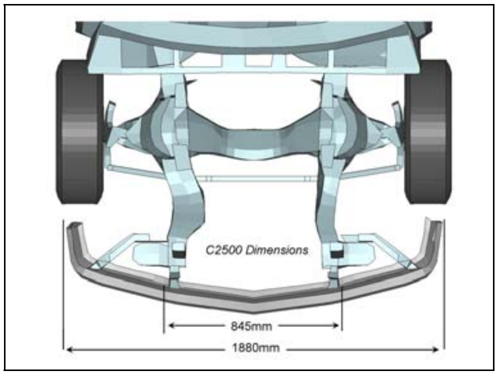

Figure 24. C2500 structural dimensions.

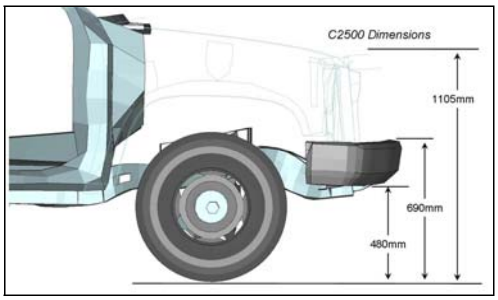

Figure 25. C2500 structural dimensions.

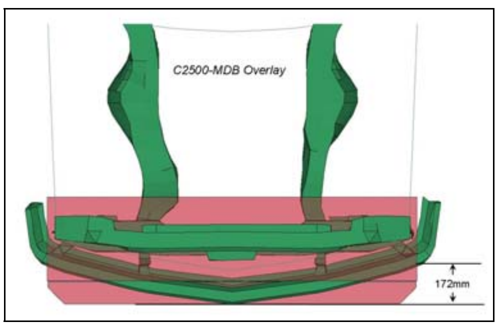

Figure 26. C2500-MDB dimension comparison.

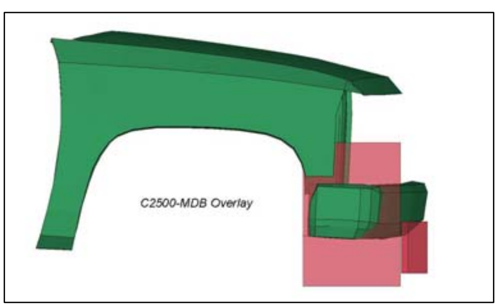

Figure 27. C2500-MDB dimension comparison.

Vehicle Structural Component Overlap

Figures 28-31 provide an illustration of the overlap of the striking vehicle structural components and the struck Taurus. These images help to show which components of the struck car that are impacted by the striking vehicle. The red areas indicate the underlying components and not the outer fascia.

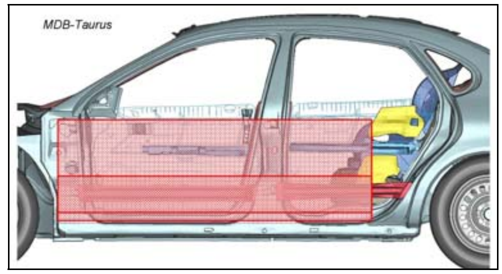

Figure 9. 214-MDB structural overlap with Taurus.

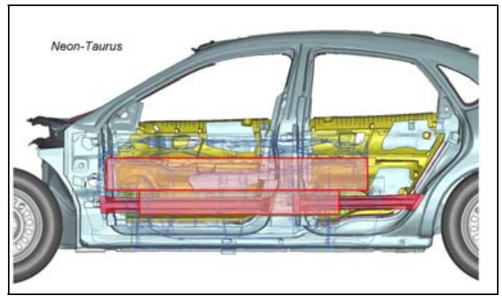

Figure 10. Neon structural overlap w/ Taurus.

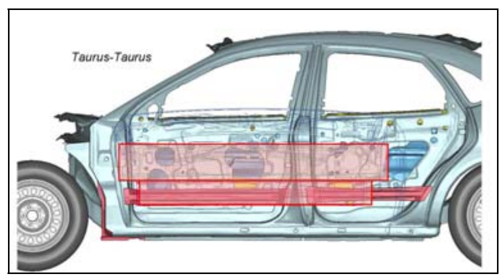

Figure 11. Taurus structural overlap w/ Taurus.

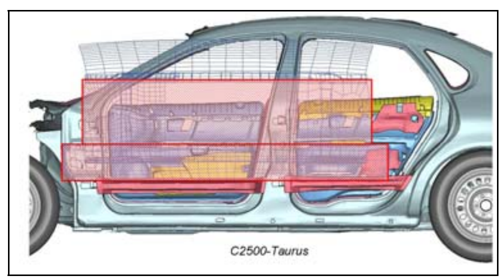

Figure 12. C2500 structural overlap w/ Taurus.

RESULTS

Individual Vehicle Crush/Intrusion Profiles

The plots shown in Figure 32-39 represent the residual post-crash position of the exterior sheet metal and interior trim surfaces relative to an exterior X-Z plane located just outboard of the widest part of the Taurus. The actual crush and intrusion values can be obtained by subtracting the ordinate value of the deformed curve from the corresponding original position of either the interior trim or exterior surface.

Tables with the values calculated are included for reference. Level-3 and 4 are only included due to space constraints, but all four levels are tabulated in Table 2.

Table 2 lists both the maximum dynamic values and the post-crush residual values for the crush and intrusion. Differences between the two values can range from 5-15% based on the springback of the Taurus structure. Timing for the peak values can be determined from the simulation results.

Included on each graph is an outline of a seated Q3 child dummy in the Vanguard child restraint. Head, pelvis, and lower extremities are marked with graphics and approximate actual dimensions. The outer edge of the child restraint shell is also depicted. This outline will illustrate the extent that the intrusion may interact with a rear child occupant. Note that the landmarks are in static pre-crash position.

MDB-Taurus

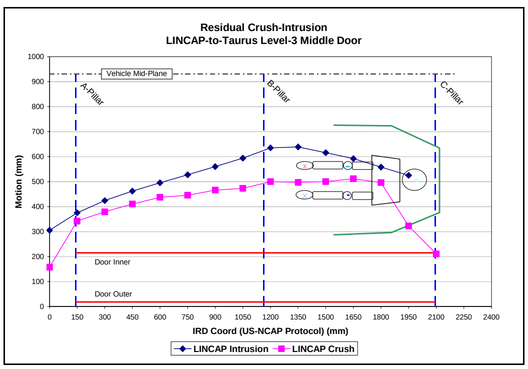

Figure 13. MDB-Taurus Level-3 (Mid-Door).

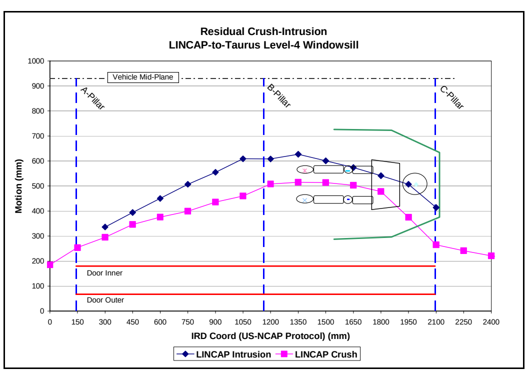

Figure 14. MDB-Taurus Level-4 (Windowsill).

Neon-Taurus Impact

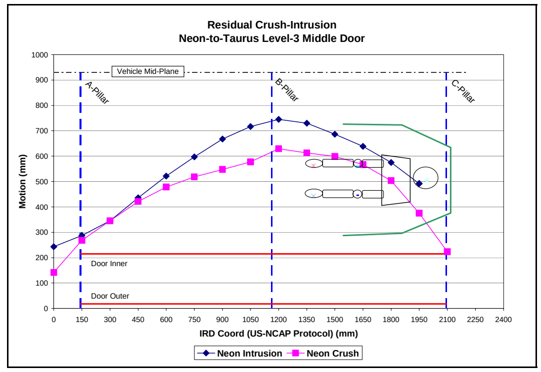

Figure 15. Neon-Taurus Level-3 (Mid-Door).

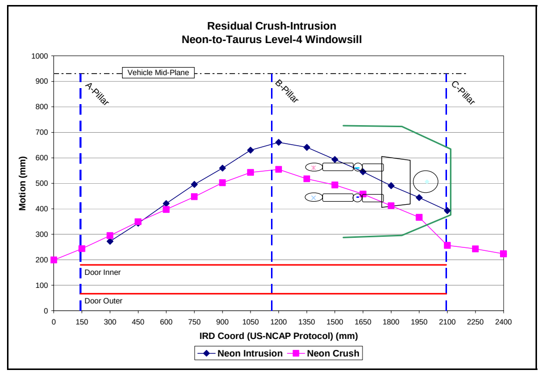

Figure 16. Neon-Taurus Level-4 (Windowsill).

Taurus-Taurus Impact

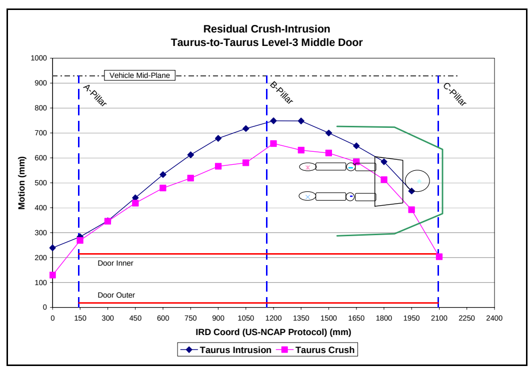

Figure 17. Taurus-Taurus Level-3 (Mid-Door).

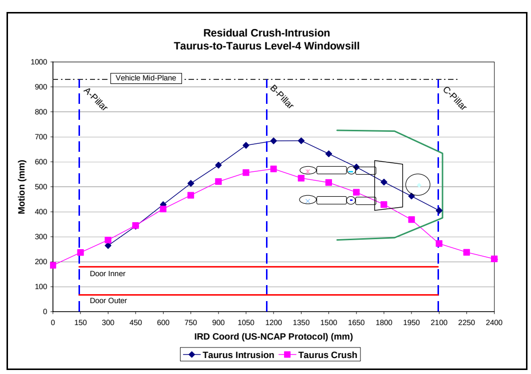

Figure 18. Taurus-Taurus Level-4 (Windowsill).

C2500-Taurus

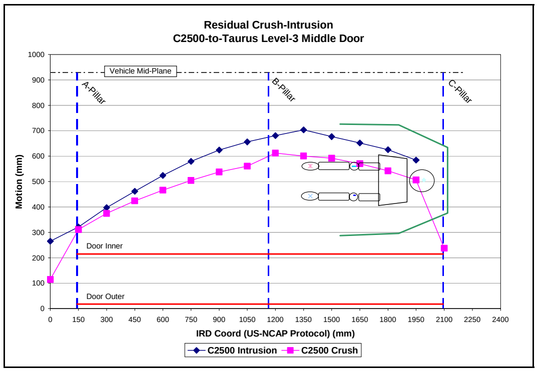

Figure 19. C2500-Taurus Level-3 (Mid-Door).

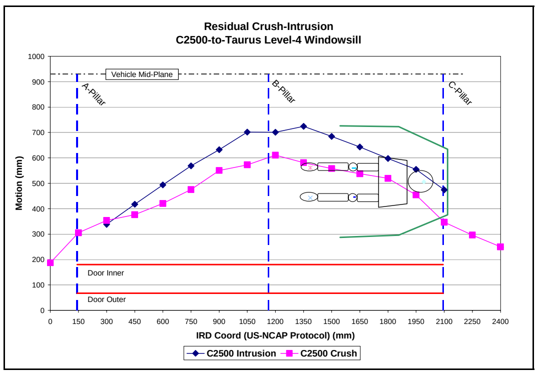

Figure 20. C2500-Taurus Level-4 (Windowsill).

Total Vehicle Crush/Intrusion Comparison

The following plots shown in Figure 40-47 are presented to show the relative differences in the struck car performance for each impacting vehicle. These graphs help illustrate the different levels of expected exterior crush or interior intrusion for each of the four crash partners.

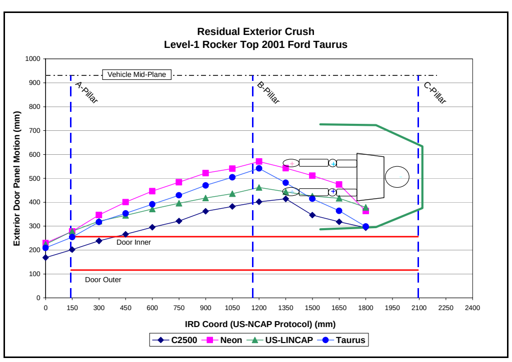

Figure 21. Taurus Level-1 (Rocker) residual exterior crush.

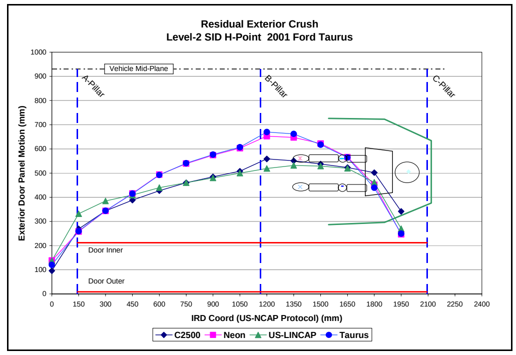

Figure 22. Taurus Level-2 (SID H-Point) residual exterior crush.

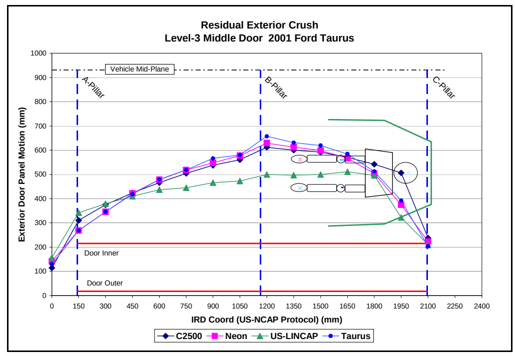

Figure 23. Taurus Level-3 (Mid-Door) residual exterior crush.

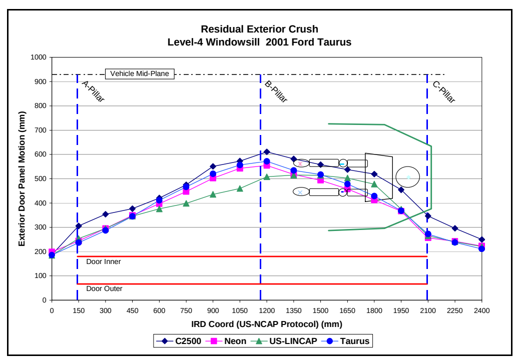

Figure 24. Taurus Level-4 (Windowsill) residual exterior crush.

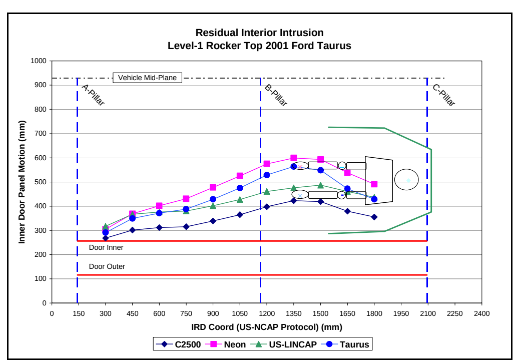

Figure 25. Taurus Level-1 (Rocker) residual interior intrusion.

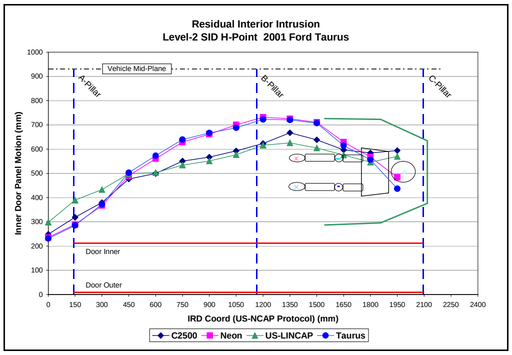

Figure 26. Taurus Level-2 (SID H-Point) residual interior intrusion.

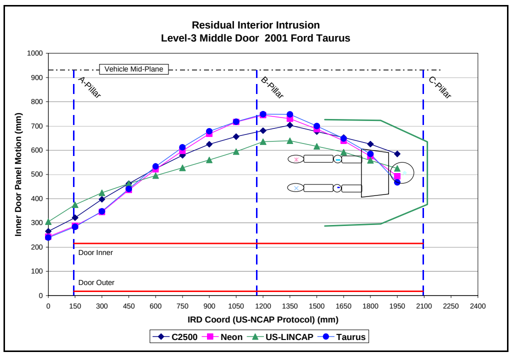

Figure 27. Taurus Level-3 (Mid-door) residual interior intrusion.

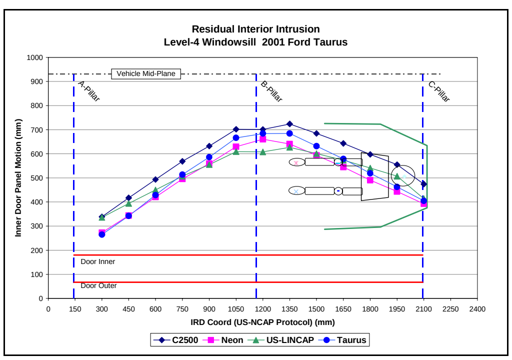

Figure 28. Taurus Level-4 (Windowsill) residual interior intrusion.

Table 2.
Level 1-4 maximum and residual exterior crush and interior intrusions

Level-1 Rocker		Max (mm)	Residual (mm)
MDB	Crush	457	346
	Intrusion	350	231
Neon	Crush	538	454
	Intrusion	433	343
Taurus	Crush	499	426
	Intrusion	386	308
C2500	Crush	380	298
	Intrusion	253	167

Level-2 SID H-Point		Max (mm)	Residual (mm)
MDB	Crush	612	523
	Intrusion	504	414
Neon	Crush	704	644
	Intrusion	577	520
Taurus	Crush	717	661
	Intrusion	571	571
C2500	Crush	615	550
	Intrusion	521	455

Level-3 Mid-Door		Max (mm)	Residual (mm)
MDB	Crush	569	493
	Intrusion	506	424
Neon	Crush	667	611
	Intrusion	576	530
Taurus	Crush	695	640
	Intrusion	587	534
C2500	Crush	657	594
	Intrusion	554	488

Level-4 Windowsill		Max (mm)	Residual (mm)
MDB	Crush	509	448
	Intrusion	510	447
Neon	Crush	519	488
	Intrusion	498	481
Taurus	Crush	546	505
	Intrusion	546	546
C2500	Crush	595	544
	Intrusion	601	544

KINEMATICS

Transient kinematic behavior of three struck side accelerometer locations and two non-struck locations are plotted in Figures 49-53. The location of the two rear door mounted accelerometers is shown in Figure 48 for reference.

Dynamic information for several locations is presented. These include the upper rear door beltline, rear door middle, lower struck side b-pillar, rear occupant compartment, and rear non-struck side rocker.

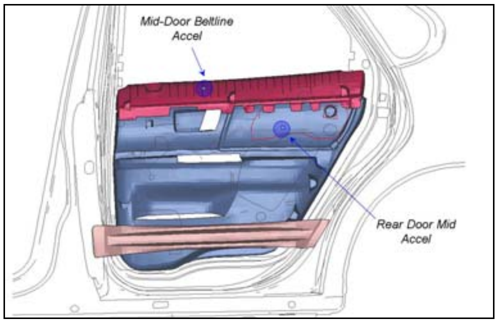

Figure 29. Rear door accelerometer locations.

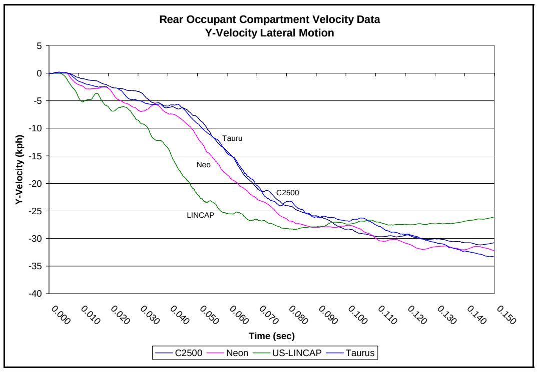

Figure 30. Rear occupant compartment Y-Velocity.

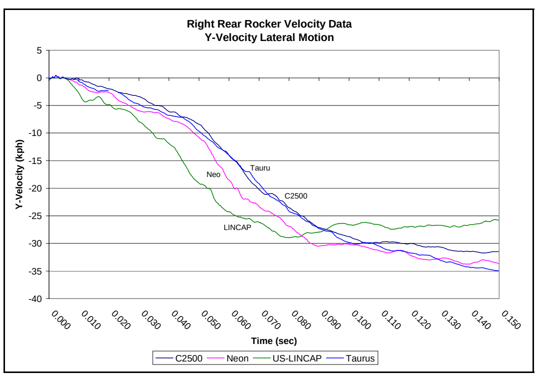

Figure 31. Right rear rocker (non-struck side) Y-Velocity.

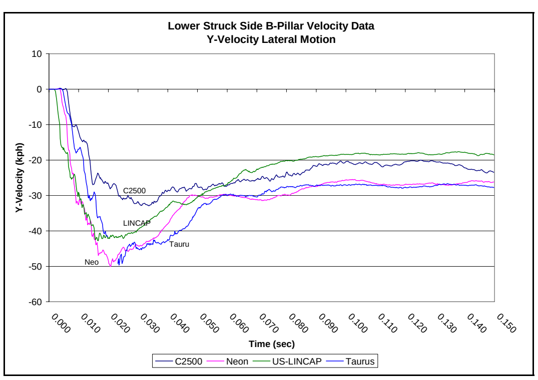

Figure 32. Lower struck side b-pillar Y-Velocity.

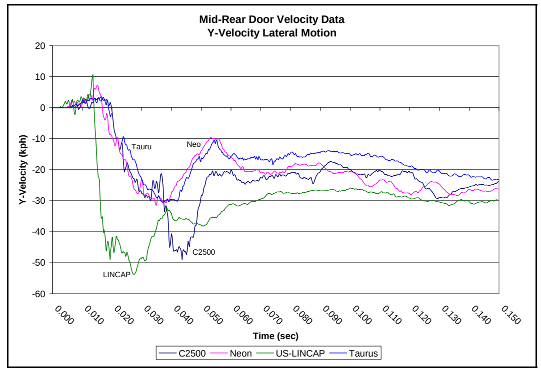

Figure 33. Mid-rear door Y-Velocity.

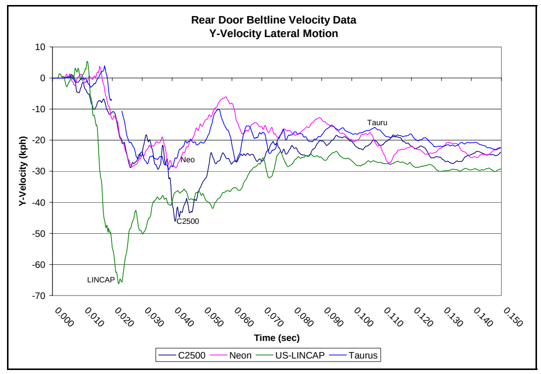

Figure 34. Rear door beltline Y-Velocity.

STRUCTURAL INTERACTIONS

A brief description of structural interactions is included in the following four sections. The purpose is to describe how the various structural interactions between the struck Taurus and the impacting crash partner produce the varying degrees of external crush, interior intrusion, and vehicle kinematics.

MDB-Taurus Side Impact

The MDB contacts the side of the Taurus with the broad, flat bumper surface and manages to contact the rocker and lower floor cross-members. The bumper of the MDB lines up exactly with the door reinforcements. The MDB does contact the front hinge pillar early in the event. The prominent structural interaction between the MDB and the Taurus produces high struck vehicle accelerations and results in a broad flat peak and residual intrusion profile. The rear door trim panel is minimally deformed and moves into the cabin in an upright manner.

An interesting result from the two door mounted accelerometers is the early and high reading as compared with the three actual vehicles. The main block of the MDB contacts the upper and mid-door outer sheet metal approximately 20-30ms earlier than any of the vehicles. This is a result of the upright design of the MDB main honeycomb block versus the sloped hoods of the sedans and to a lesser extent the pick-up truck. In addition the upper beltline accelerometer is almost cantilevered since the upper edge of the MDB contacts outer sheet metal several centimeters rearward of the accelerometer mounting point. This creates a velocity that exceeds the impacting MDB velocity.

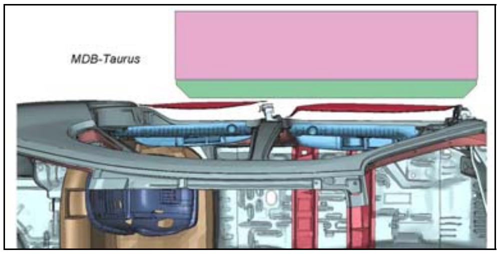

Figure 35. MDB-Taurus structural overlap.

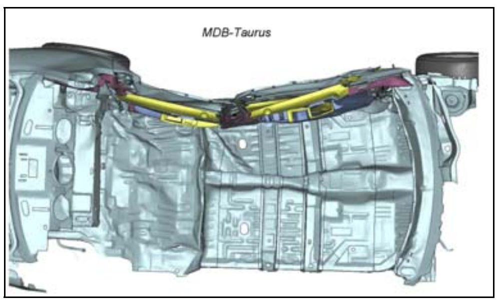

Figure 36. MDB-Taurus post-impact deformations.

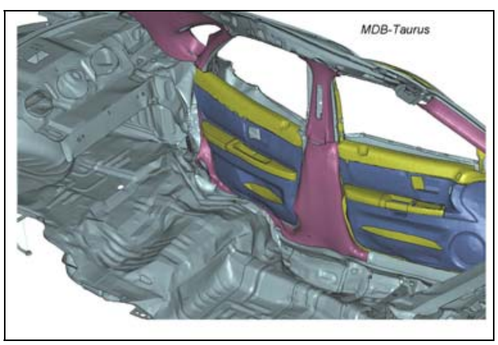

Figure 37. MDB-Taurus post-impact interior intrusion.

Neon-Taurus Side Impact

The Neon front end is narrower than the other bullet vehicles. During the contact with the Taurus, the front structural bumper misses the rocker and both the front hinge pillar and rear wheel-well, although it does contact the door reinforcements. Later in the event, the lower front sub-frame of the Neon impacts the rocker and cross-members of the Taurus resulting in the delayed acceleration to the overall struck vehicle.

The narrow front end protrudes deeply into the body of the Taurus and results in a noticeable arcing of the inner door panels and b-pillar. The lower sections of the door panels tip inward, but the upper windowsill does remain straight and relatively undeformed. It is interesting to note that at the lower vertical measurement heights, the Neon produces significantly more intrusion than the Taurus, MDB, or C2500

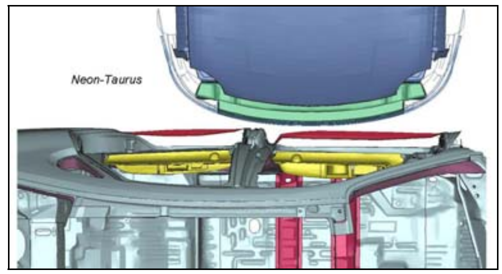

Figure 38. Neon-Taurus structural overlap.

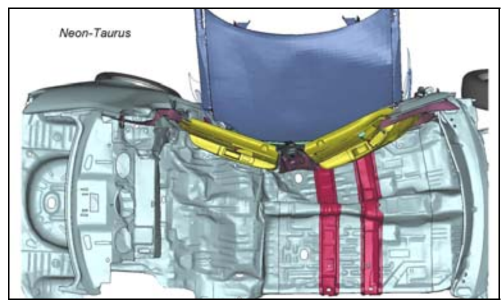

Figure 39. Neon-Taurus post-impact deformations.

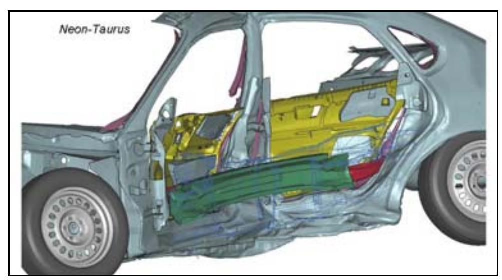

Figure 40. Neon-Taurus structural interaction.

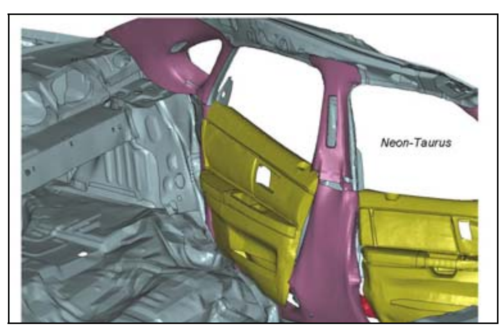

Figure 41. Neon-Taurus post-impact interior intrusion.

Taurus-Taurus Side Impact

The Taurus impacting vehicle behaves similarly to the Neon except that the front end bumper is wider and the intrusion height seen in the door panels is higher. The intrusion of the rear door is greatest at the mid-height of the door with the upper windowsill remaining straight and undeformed.

The bumper of the Taurus overrides the rocker, but later in the event the lower structure engages the floor and cross-members. The resulting velocity change in the struck Taurus is delayed compared to that of the Neon or MDB, mainly due to the later engagement of lower floor cross-members.

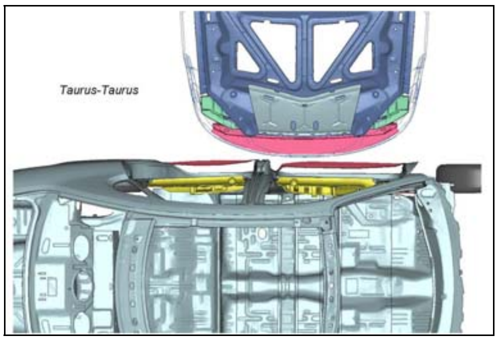

Figure 42. Taurus-Taurus structural overlap.

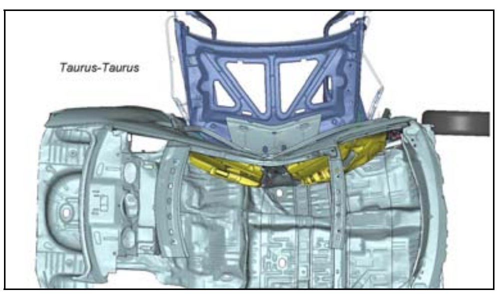

Figure 43. Taurus-Taurus post-impact deformation.

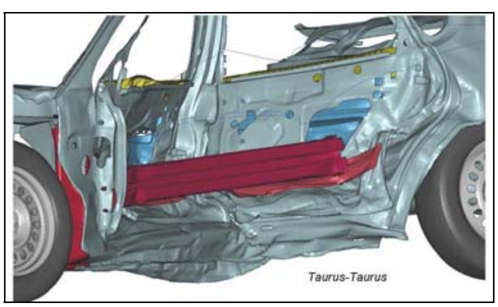

Figure 44. Taurus-Taurus structural interaction.

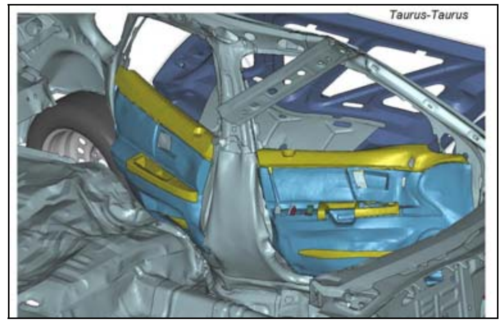

Figure 45. Taurus-Taurus post-impact interior intrusion.

C2500-Taurus Side Impact

The C2500 features a wide structural front bumper that is rigidly mounted onto the main frame rails and support members. The bumper overrides both the rocker and door reinforcements of the Taurus and causes a tipping of the upper interior door trim and b-pillar. The bumper does however engage the front hinge-pillar and rear wheel-well. This contact with stiff BIW components and the overall width of the bumper helps broaden the shape of the intruding surface and minimize the local punching effect that both sedans exhibit.

The overall acceleration to the struck car is somewhat lower that the MDB and Neon since the lower floor and cross-car members are not engaged as is evident from the low crush at Level-1. The C2500 does produce the greatest amount of intrusion at the windowsill vertical measurement height.

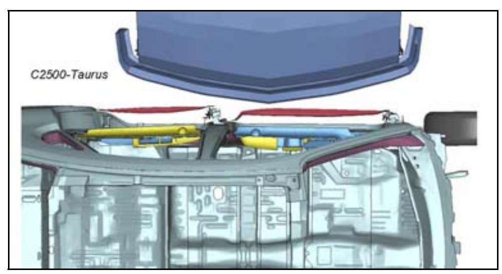

Figure 46. C2500-Taurus structural overlap.

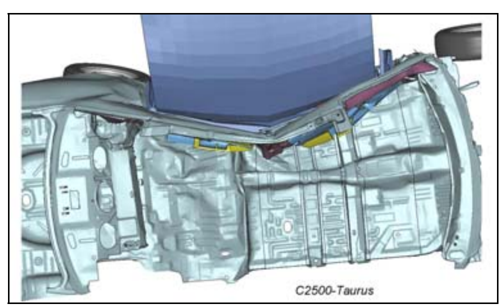

Figure 47. C2500-Taurus post-impact deformations.

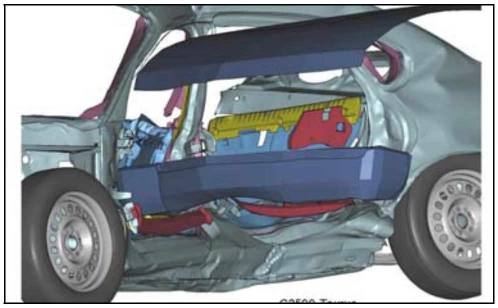

Figure 48. C2500-Taurus structural interaction.

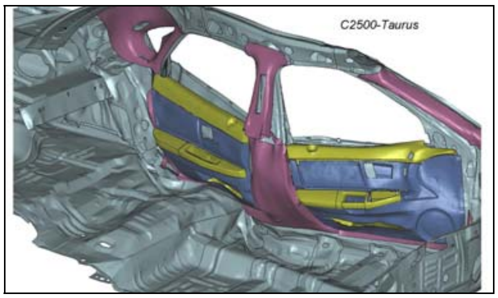

Figure 49. C2500-Taurus post-impact interior intrusion.

DISCUSSION

There are two outcomes from this data that is of interest depending upon the seating location of a restrained child involved in a side impact. For those seated nearside, the rear occupant compartment intrusion and intrusion rate will most likely be the most influential factors in producing injury. Farside occupants and middle row occupants may most likely be sensitive to the struck vehicle overall kinematics.

The results of the simulations help illustrate the effect of the impacting partner on the four parameters of interest. Given that real world side impacts can occur with any type of object or vehicle, having data on crash outcomes for a broad mix of impacting partners will help frame the crash conditions that can be considered for a laboratory assessment.

The benefit of the simulation is a clear illustration of the structural interaction between the two vehicles involved in the impact. Localized damage to specific vehicle parts and the way that these contact a rear child occupant can be examined in detail. Used appropriately in conjunction with data from actual tested vehicles, the simulation serves as a valuable tool for examining alternative crash modes. The vehicle models clearly illustrate the breadth of damage potential and vehicle motion and can be used to further determine the range of damage that a rear seated occupant may be subjected to.

CONCLUSSION

The data briefly described in this report is only a small illustration of the resulting structural deformation of a mid-size sedan subjected to specific side impacts. A child seated in a rear row of a mid-size sedan can find themselves in collisions similar to these. Understanding the potential range of intrusions that the child may contend with can be partially fulfilled with this data. As field investigations have indicated, intrusion is a significant factor leading to injury, being able to describe the range and type of intrusion for a broad spread of striking vehicles is necessary in order to determine injury mechanism and create effective countermeasures.

Additional assessments using non-vehicle striking objects should be added to broaden the data set for single-vehicle side impacts. Once a satisfactory amount of data has been developed to describe the rear seat environment, the project can move from full vehicle assessments into sub-system testing and evaluation. At this point detailed analysis of child restraints and child occupant dummies can be used to help determine injury mechanism.

ACKNOLWEDGMENTS

The funding for this research has been provided [in part] by private parties, who have selected Dr. Kennerly Digges [and FHWA/NHTSA National Crash Analysis Center at the George Washington University] to be an independent solicitor of and funder for research in motor vehicle safety, and to be one of the peer reviewers for the research projects and reports. Neither of the private parties have determined the allocation of funds or had any influence on the content of this report.

REFERENCES

1. Arbogast, K., et al. Child restraints in side impacts. Proceedings of the International Conference on the Biokinetics of Impact Attributes. 2004. Graz, Austria.

2. Tamborra, N., Bahouth, G. Child Side Impacts: Comparison of Vehicle Crush in Side Impacts from Field Investigations and U.S. Consumer Tests. SAE International Congress and Exposition. 2005. Detroit, MI: Society of Automotive Engineers, Inc.