1. INTRODUCTION

1.1 Background

This report details the changes to the revision 1 of the IIHS deformable bumper barrier CAE model to create revision 2 of the CAE model. Furthermore it describes in detail the correlation study performed using the revision 2 of the CAE model.

1.2 Units

The models are supplied in the following units:

Time: milliseconds

Length: millimeters

Force: Kilo Newton

Mass: Kilo Grams

Models in other user required units are available upon written request.

1.3 Computer Hardware & Software

The analyses were executed on an HP Workstation XW 6000 computer. HyperMesh 7.0 was used for model generation. Analysis was conducted using LS-DYNA 970.

1.4 Contact Names

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2. IIHS Deformable Barrier Model

The Finite Element model of IIHS Deformable Barrier Model consists of the three following components: The fascia or (bumper cover), the energy absorber, and the rigid barrier mounting structure.

2.1 Finite Element Model Construction

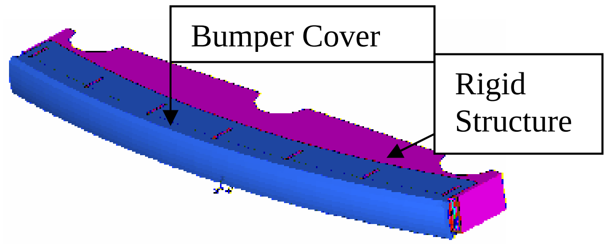

Figure1: Finite Element Model with Bumper Cover

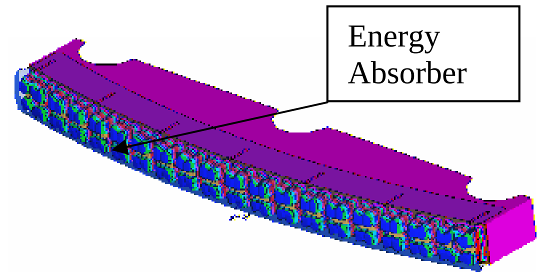

Figure2: Finite Element Model Fascia Transparent

2.2 Model Details:

The model contains 3 main components:

1. The fascia (bumper cover) – High Density Polyethylene Material
2. The Energy Absorber – High Density Polyethylene Material

The Rigid Structure (IIHS Defined Barrier) – Rigid Material

2.3 Changes from Revision1:

- *Refinement*: The finite element mesh of the energy absorber was refined to capture the finer details of the geometry.
- *More detailed thickness variation representation*: In order to accurately capture the thickness variation caused by stretching of the material in thermoforming process, the finite element model is divided into numerous collectors representing part thickness at respective locations. Revision 1 model was divided into 10 collectors while the revision 2 model is divided into 25 collectors representing thicknesses.

- *Detailed stress-strain curve*: In order to capture the material characteristics accurately, a detailed effective stress-effective plastic strain derived directly for the tensile testing of the material was used.
- *Strain Rate effects*: In order to capture the material characteristic at different speeds, strain rate obtained through material testing done by the material supplier was also applied to the material model.
- *Control cards*: A few new control cards were added to improve correlation. The added cards are - *CONTROL_BULK_VISCOSITY, *CONTROL_CONTACT, and *CONTROL_SHELL.

2.2 Model statistics are as follows:

	Revision 1	**Revision 2**
Number of deformable nodes	13886	47138
Number of deformable elements	14322	48846
Number of rigid nodes	352	352
Number of rigid elements	324	324

2.3.1 Material Models:

For HDPE material - *MAT_PIECEWISE_LINEAR_PLASTICITY (MAT24)

For Rigid Structure - *MAT_RIGID (MAT20)

2.3.2 Element Formulations: ELFORM 16 and NIP 5 options were used for all deformable elements to capture the potentially significant plastic deformation of the components.

2.4 Contact Definitions:

The internal contact is defined by *AUTOMATIC_SINGLE_SURFACE_ID. All the components are included in this contact.

The Energy Absorber is attached to the rigid structure by *XTRA_NODES at the designated mechanical "push pin" locations. The fascia is constrained to the rigid bumper barrier by single point constraints (SPC's) allowing translation in the "X" or fore-oft direction to mimic the sliding motion of the push-pin guides in the slots on the fascia.

3. Model Validation and Correlation

Revision1 of the CAE model was validated with a 3.0 mph flat barrier impact. Fig.3 shows a good level of correlation of CAE to the physical test. Consistent results of the physical tests show a good level of repeatability.

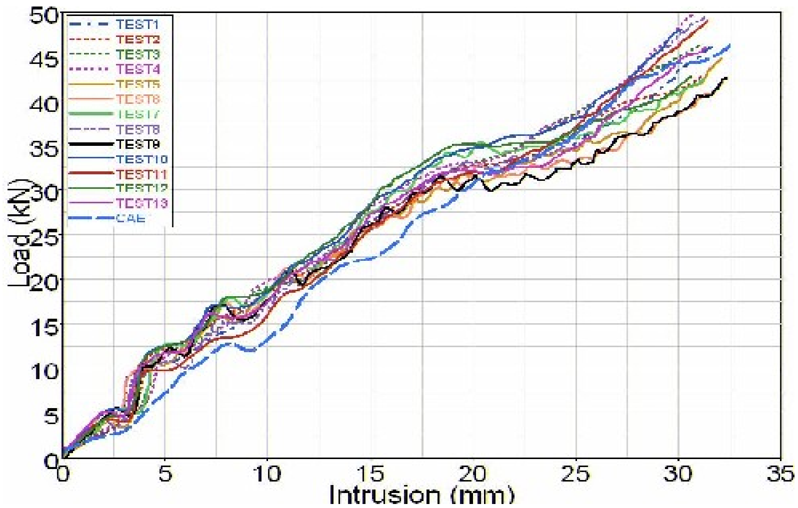

Figure 3: Correlation for revision 1; 3mph flat barrier impact

Revision 2 of the IIHS bumper barrier CAE model was subjected to very extensive validation testing. To validate the IIHS bumper barrier across a wide range of vehicle types, several bumper system constructions were tested using the physical parts of IIHS deformable bumper barrier on a Universal Test Vehicle (UTV) shown in Fig.4. Following the physical tests, CAE simulations were performed using the virtual universal test vehicle (VUTV) shown in Fig.5.

Figure 4: Universal Test Vehicle

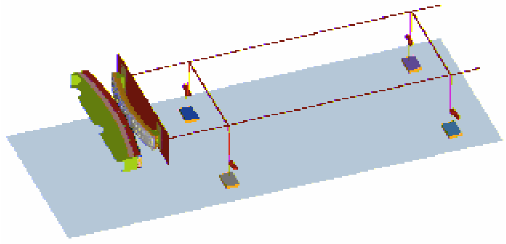

Figure 5: Virtual Universal Test Vehicle

The following comparisons in Figures 6 to 12 show a very good level of correlation of the CAE simulations to the physical tests and confirms the robustness of the model to numerous test conditions.

Figure 6 shows that the CAE results correlate very well to the physical test curve of the bumper system that includes a steel roll formed beam and an EPP foam absorber. The IIHS Bumper Barrier energy absorber undergoes excessive deformation during the initial part of the impact. The initial load ramp up (till 80mm of intrusion) is “line-on-line”, showing that the CAE model of the IIHS bumper barrier behaves very closely to the physical part. The simulation also captures the beam buckle failure mode (load drop comparison at ~90 mm) seen in physical test. Lastly the vehicle dive and slight rebound is also well captured in CAE simulation as shown by the last part of the curves.

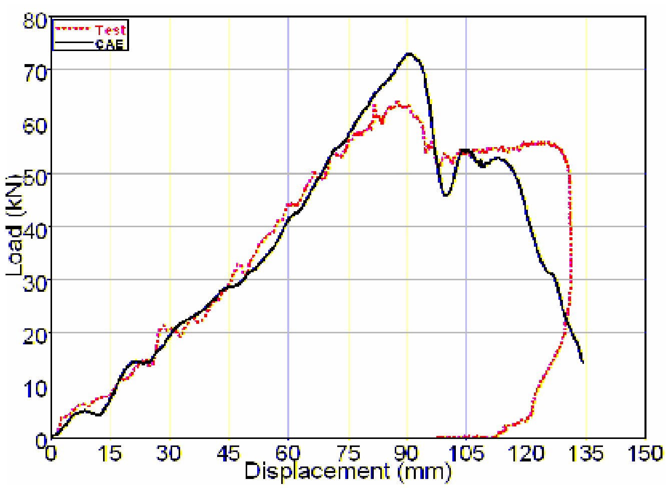

Figure 6: Correlation for Midsize Sedan – Roll Formed “B” Section Bumper Beam with EPP Foam Energy Absorber – 10 km/h IIHS Bumper Barrier Test

Figure 7 also shows a good level of correlation of CAE simulation to physical test for a Cross over vehicle bumper system which includes a roll formed steel bumper beam and an injection molded TPO absorber. The initial load ramping, the peak load and the rebound are accurately captured by the CAE simulation. Again, the initial part of the F-D curves (till 80 mm of intrusion) match “line-on-line” showing a very high level of correlation between physical part and the CAE model of the bumper barrier.

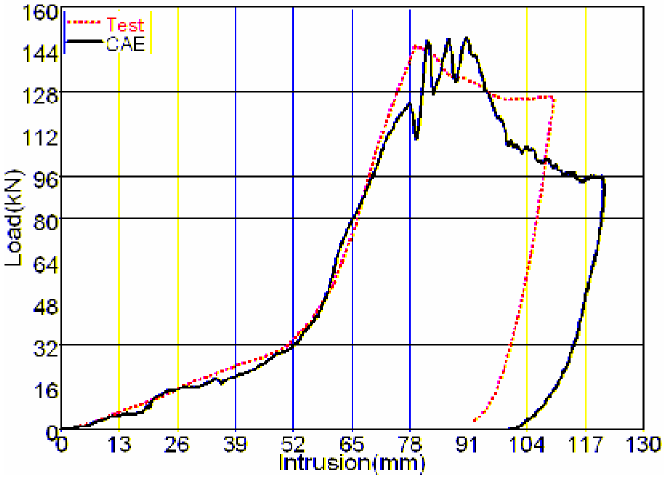

Figure 7: Correlation for Crossover Vehicle – Roll Formed "B" Section Bumper Beam with Injection Molded TPO Energy Absorber – 10 km/h IIHS Bumper Barrier Test

Figure 8 shows how closely the CAE simulation for the cross over vehicle bumper system (F-D curves shown in Fig.7) predicts the beam buckle behavior as seen in the physical test (Fig. 9).

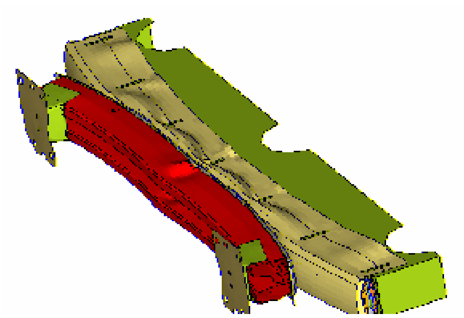

Figure 8: Cross over Vehicle Bumper System Showing Beam Buckle in CAE Simulation

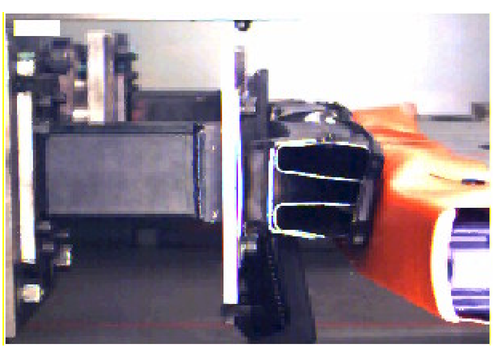

Figure 9: Cross over Vehicle Bumper System Showing Beam Buckle in Physical Test

Fig. 10 shows a very close correlation between CAE and physical test for a minivan bumper system, which used an extruded aluminum bumper without an energy absorber. The initial ramp up again shows how closely the CAE model of the IIHS bumper barrier correlates to the actual physical part behavior.

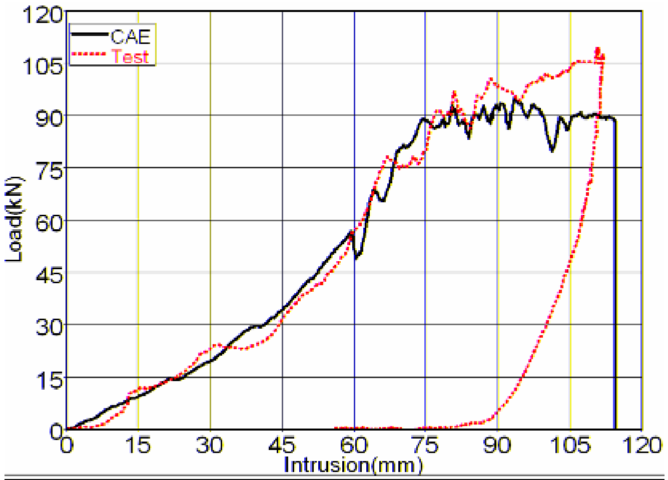

Figure 10: Correlation for Minivan Bumper System - Extruded Aluminum Bumper – 10 km/h IIHS Bumper Barrier Test

The results for a Midsize car with a bumper construction that comprises a roll-formed "B" section bumper beam and an injection molded PC/PBT energy absorber are shown in Figure 11. Once again the rate of loading, maximum loads and intrusions are captured very closely using the described CAE model. The ability to represent the vehicle dynamics, in terms of vehicle vertical movement (dive) and rebound has also been established and is vital to the ability to determine whether the bumper system will under/override the barrier.

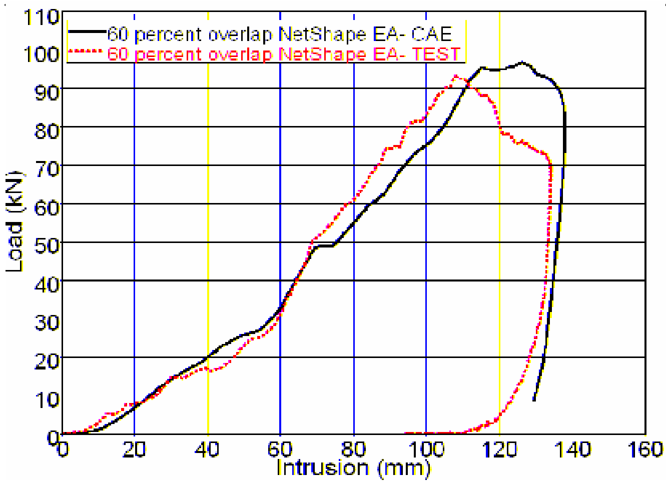

Figure 11: Correlation for Mid-size Sedan - Roll Formed "B" Section Bumper Beam with Injection Molded Energy Absorber – 10 km/h IIHS Bumper Barrier Test

For the final test a Mid-size car with a bumper construction that comprises a roll-formed "B" section bumper beam and an EPP energy absorber was run. The results shown in Figure 11 indicate that the bumper system lost some engagement and the CAE simulation captured the under-ride effectively.

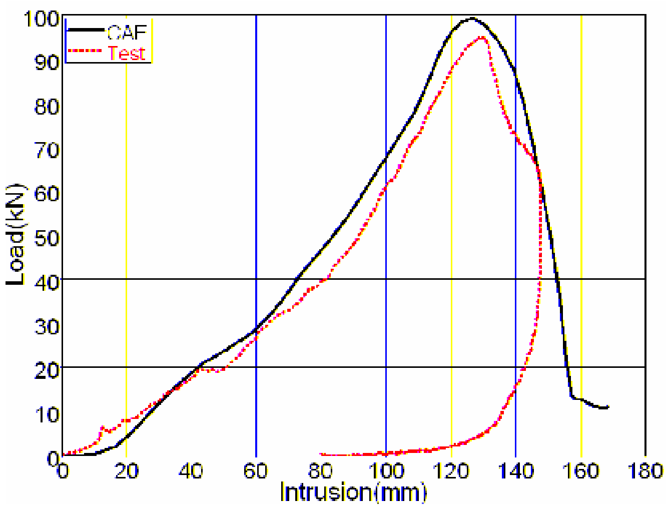

Figure 12: Correlation for Mid-size Sedan - Roll Formed "B" Section Bumper Beam with EPP foam Energy Absorber – 10 km/h IIHS Bumper Barrier Test