

INTERIOR AND RESTRAINT SYSTEMS MODELING FOR OBLIQUE OFFSET FRONTAL IMPACT

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ABSTRACT

National Highway Transport Safety Administration (NHTSA) has been investigating oblique offset frontal impact test conditions. This research developed a validated occupant interior and restraint systems that could be used to evaluate the kinematics and injury implications for frontal crash test conditions. The objective was to develop validated oblique offset crash simulations using both Test device for Human Occupant Restraint (THOR) dummy model and human body models. The vehicle selected for this Computer Aided Engineering (CAE) study was a 2014 Honda Accord. The vehicle interior was scanned and modeled and restraint characterization tests were conducted. The occupant interior finite element (FE) model was developed and validated against available test data. FE models for THOR dummies were seated in driver and passenger seats and validated against both left and right oblique offset test results. Subsequently, the 50th percentile FE Human body model from Global Human Body Models Consortium (GHBMC) was seated in the vehicle and the kinematics was compared against the THOR dummy model. The outcome of this study was to develop realistic FE models that could be used to investigate how crash test conditions can affect optimal occupant restraint system design. The results predicted from the CAE simulations of the baseline vehicle model demonstrated similar safety performance to the available vehicle test results in terms of vehicle acceleration and intrusion responses in NCAP frontal, IIHS moderate overlap, IIHS small overlap test procedures, and left and right NHTSA oblique frontal tests. The CAE simulation results compared well with test results for THOR dummy model accelerations and injury criteria. A comparison of occupant kinematics, belt loads and injury criteria against the simulations using the GHBMC model also was done. The CAE simulation results using the GHBMC also compared well with test and CAE results of using THOR dummy model.

INTRODUCTION

The occupant safety performance in some of the newer frontal crash test conditions, particularly oblique frontal crash tests, is dependent on the occupant interaction with the intruding vehicle components and the vehicle restraint system. It is desirable to develop full vehicle finite element models that can be used to study how changes in frontal crash test conditions can affect the occupant interaction with the restraint systems and the occupant injury outcomes. In this research, it was intended to develop a full vehicle finite element model, including the vehicle interior and occupant restraint systems for the driver and front seat passenger simulations using THOR dummy model and human body models.

The selected vehicle for this research was the 2014 Honda Accord as the CAE model was readily available from NHTSA's structural countermeasure program [1]. The chosen vehicle met the structural intrusion requirements of "Good" in both IIHS small and moderate overlap and 5-star in NCAP rating. The test procedure for CAE simulation used involves a high-speed oblique moving deformable barrier (OMDB) hitting a stationary vehicle with a 35-percent overlap at an angle of 15 degree from collinear, in both left and right. This test was conducted to replicate vehicle damage and occupant kinematics based on one of the common configuration crashes with belted occupant fatalities in vehicles with airbags [2].

The oblique frontal crash test currently uses the THOR dummy for evaluating occupant responses in the test vehicles. Currently, there are two finite element models available for THOR dummy. One version is publicly available from the University of Virginia, another is commercially available for lease from Humanetics, Inc. For this study, the University of Virginia THOR dummy model V2.1 of 50th percentile male occupant was used.

Additionally, there is considerable interest in using finite element models of the human body to compare their response and kinematics against the test dummies. Human body models that are commonly used for automotive research include the GHBMC model and the Total Human Model for Safety (THUMS) model from Livermore Software Technology Corporation. For this study the GHBMC 50th percentile male occupant Version 4.5 for LS-DYNA was leased from Elemance, LLC.

This paper describes the stages of CAE modeling and simulations. The initial step in the study was to obtain correlation between the actual oblique offset test performed by NHTSA and the CAE simulation. The parameters observed during the correlation task were THOR dummy model kinematics, airbag deployment and behaviors, seatbelt resistance force and occupant injury measures. When the simulations were correlated, the THOR models were replaced by GHBMC model and comparisons were made between the simulations of using THOR and GHBMC models.

VEHICLE INTERIOR MODEL DEVELOPMENT

The vehicle model was updated with vehicle interior and occupant restraint systems for the driver and front-seat passenger. White light scanned computer aided design (CAD) data for the interior of 2012 MY Honda Accord was used to represent the interior geometry of all relevant parts: instrument/dash panel assembly, center console, driver, and passenger seat. Occupant restraints system included airbags and seatbelts. Airbags and seatbelts were tested by conducting physical tests such as airbag deployment test and seatbelt pull test. They were then validated with the CAE simulations before integrating them in the full vehicle model. The details of FE modeling of interiors and restraint systems testing is out of the scope of this paper.

VEHICLE OBLIQUE OFFSET FRONT TEST SIMULATION – THOR AND HUMAN MODEL (GHBMC)

This test is used to determine the crashworthiness of the vehicle to protect occupants in offset frontal impact crash cases. The test consists of an oblique moving deformable barrier (OMDB) that weighs 2,490.2 kg traveling at a target speed of 90.12 km/h into a stationary vehicle as shown in Figure 1. The struck vehicle is positioned 15 degrees relative to the moving barrier and impacted 35 percent of the left or right side of the vehicle.

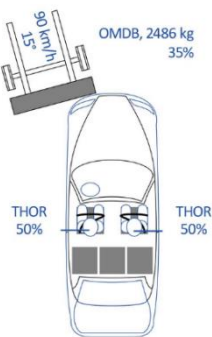


Figure 1. NHTSA Oblique Offset Setup.

THOR dummy model was duplicated into two models to have both driver and passenger. The two THOR dummy models were positioned on the vehicle driver and passenger seat respectively. It should be noted that the seat cushion foams were pre-deformed to accommodate dummies pelvic shape. Two-dimensional (2D) shell element seatbelts were modeled by routing over the shoulder and lap parts of the dummy models. The full vehicle model with the occupant models and restraint systems were checked for standard finite element model quality requirements such as connectivity, time-step and outputs. The model was run in LS-DYNA crash simulation solver for 200 milliseconds.

After the crash simulations with THOR dummy models were performed, using the THOR dummy models, another set of FE model were created by replacing the THOR dummy models by GHBMC models. Likewise, for this purpose, GHBMC model was duplicated into two models, respectively for driver and passenger. Once again, the full vehicle model with GHBMC models were run in LS-DYNA for 200 milliseconds. A comparative simulation results of test, THOR dummy models and GHBMC models are discussed in the following section.

CAE RESULTS DISCUSSION

At first the CAE results of full vehicle model oblique offset frontal impact case using THOR dummy models are compared to the test results. Next, the CAE results of the same using THOR dummy models are compared to CAE results of using GHBMC models.

Figure 2 shows crash simulations using THOR dummy models at 0ms (before crash) and at 120ms (after crash) comparing the test and CAE of THOR dummy models. It can be observed that both driver and passenger airbag deployed at 14ms and curtain airbag deployed in 42ms. Also, at 14ms, the seat belt pre-tensioner fired and tightened any slack defined as length of 25mm. At 120ms the driver dummy's head got sandwiched in between the driver airbag and curtain airbag, meanwhile the passenger dummy's head impacted the dashboard. Overall the kinematics of the CAE simulations and THOR dummy models show good correlation with the test results.



Figure 2. Test vs CAE simulations using THOR dummy models at 0ms (before crash) and 120ms (after crash).

Similarly, Figure 3 shows crash simulations using GHBMC models at 0ms (before crash) and at 120ms (after crash) while comparing THOR dummy models and GHBMC models. It can be observed that the deployment time of airbags and seatbelt pre-tensioner are similar to the simulation using THOR dummy models. In terms of kinematics, the behavior of the GHBMC models was found to be similar to the THOR dummy model except for the seatbelt behavior on the passenger side. Unlike THOR dummy models, in the GHBMC model, the seatbelt did not completely slip off the shoulder, resisting it to impact on the dash.

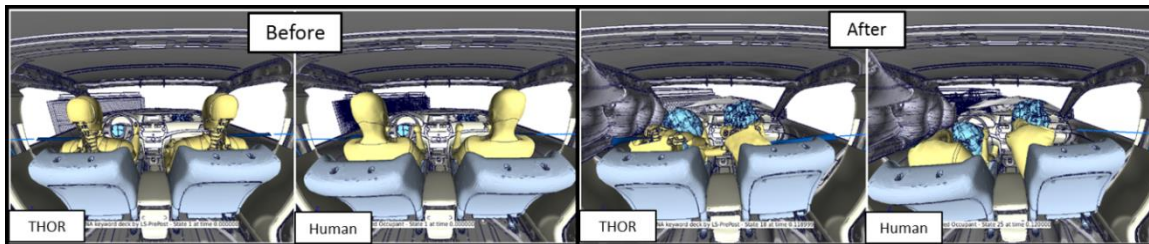


Figure 3. CAE-THOR vs CAE-GHBMC at 0ms (before crash) and 120ms (after crash).

Figure 4 compares the CAE results' head CG acceleration of the driver and passenger with that of test results. For the driver side, the overall trend of the acceleration curves shows a decent correlation among all three events. The passenger side did not correlate well due to the different seat-belt behavior while slipping off the shoulder which was observed in the test. In the THOR dummy model simulation, even though the seatbelt slip-off occurred, the seatbelt still provided some resistance that reduced the head impact to the dash. In the GHBMC model simulation, the seatbelt did not slip-off due to high friction with the skin, hence stopping the GHBMC model from moving forward and contacting the dash.

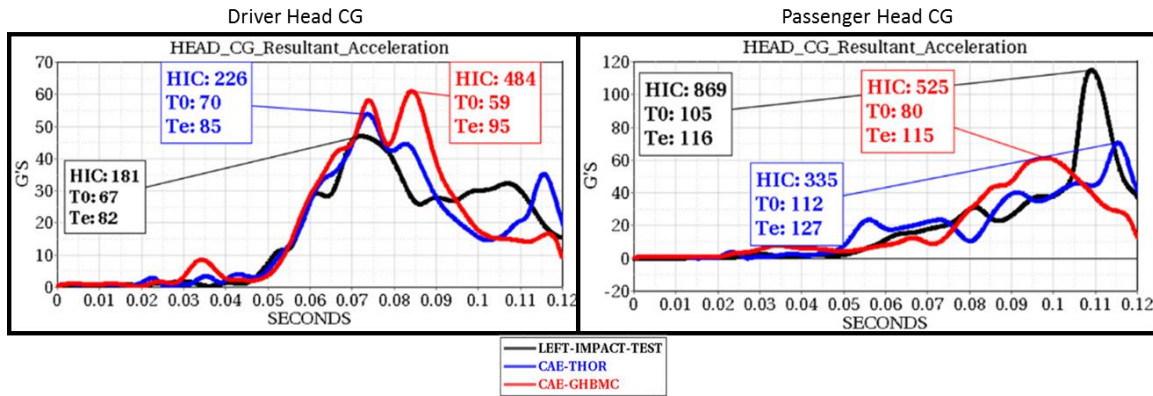


Figure 4. Driver and Passenger Head CG Acceleration.

Figure 5 shows the driver and passenger femur forces. In the THOR dummy model, the force was measured from a beam element that connects two metal sockets moving axially between each other along the femur. In the GHBMC model, the force was taken from a cross-section force of the actual femur bone made of solid elements. The GHBMC model seemed to experience more load through the femur compared to the THOR dummy model.

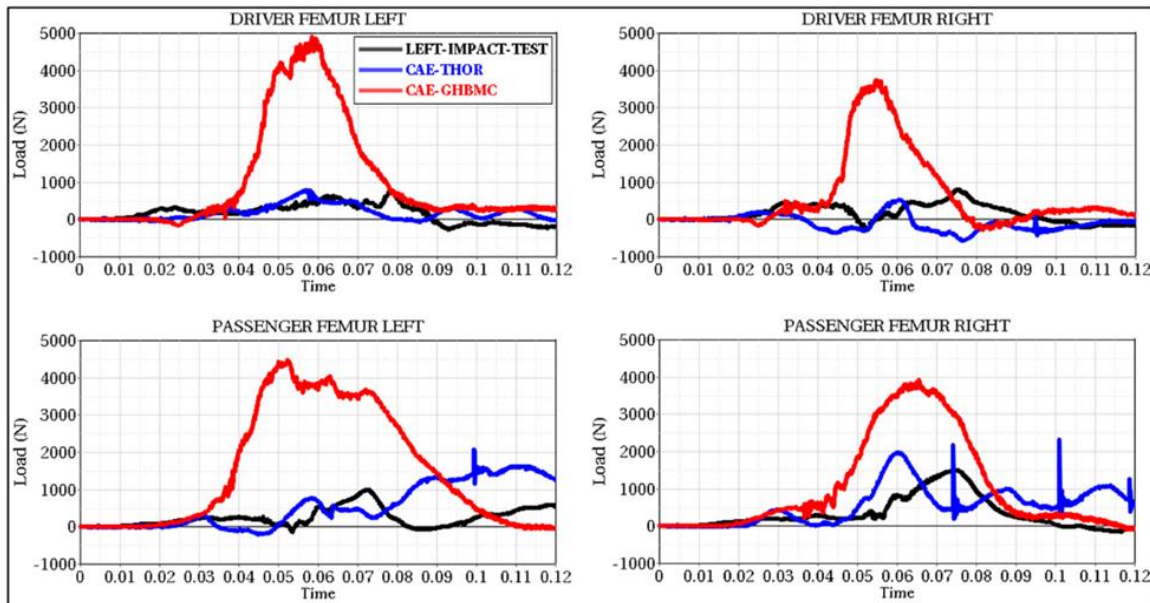


Figure 5. Driver and Passenger Femur Force.

More comparisons such as pelvic accelerations, seatbelt forces, and detailed timeline images of crash and complete right-side impact of oblique offset test can be referred in the full project report [3].

CONCLUSION

Full vehicle finite element models representing 2014 Honda Accord including interior trims and occupant restraints system were developed in this research. The occupant restraint system such as the airbags and seatbelt were tested and validated with the CAE models before they were integrated into the model. The full vehicle used THOR 50th percentile male dummy model to represent both driver and passenger. NHTSA's Oblique Offset front impact test simulations were carried out for both left and right-side impacts. The overall dummy kinematics of THOR dummy model in CAE simulation correlated well with the test. There was a slight difference found in the head to dash interaction due to the difference in seatbelt behavior during the event whether it slipped off the shoulder of the passenger or not. The simulations were repeated by replacing THOR dummy models by GHBMC models. GHBMC models showed similar overall kinematic behavior during the crash event compared to THOR dummy models. Unlike THOR dummy model, in case of passenger side GHBMC model, the seatbelt did not slip off the shoulder due to high friction with the skin, causing it to resist the forward motion. This prevented the GHBMC model head to collide with the dash as seen otherwise in the passenger THOR dummy model. It was also observed that the GHBMC model femur forces were much higher compared to THOR dummy femur forces.

REFERENCES

- [1] Singh, H., Ganesan, V., Davies, J., Paramasuwom, M., Gradischnig, L., Wood, P., et al. (2018). Structural Countermeasure/ Research Program: Mass and Cost Increase Due to Oblique Offset Moving Deformable Barrier Impact Test. NHTSA.
- [2] Bean, J. D., Kahane, C. J., Mynatt, M., Rudd, R. W., Rush, C. J., & Wiacek, C. (2009, September). Fatalities in frontal crashes despite seat belts and air bags – Review of all CDS cases – Model and calendar years 2000-2007 –122 fatalities (Report No. DOT HS 811 102). Washington, DC: National Highway Traffic Safety Administration.
- [3] Singh, H., Ganesan, V., Davies, J., & Paramasuwom, M. G. (2018). Vehicle Interior and Restraints Modeling Development of Full Vehicle Finite Element Model Including Vehicle Interior and Occupant Restraints Systems for Occupant Safety Analysis Using THOR Dummies. NHTSA.