Comparison of Hybrid III Rigid Body Dummy Models

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Abstract

Hybrid III Dummy Computer Aided Engineering (CAE) models have long been used for aspects of vehicle design, including vehicle structure and restraint systems to meet regulatory safety rating targets and internal company requirements. The quality and run time of these CAE models in simulating physical dummies directly affects the usefulness of CAE tools in vehicle development. The objective of this study is to compare the responses of the Madymo Rigid Body dummy and the LSTC Rigid-FE dummy in four crash test modes of one vehicle. During the study, in order to have a fair and sound comparison, the authors have requested each of the companies (TASS and LSTC) to examine the performance of their respective dummy models in essentially the same vehicle environment model. The authors would like to acknowledge their efforts and comments.

In particular, frontal crash test modes using the passenger belted and unbelted 50th percentile male Hybrid III dummy and the passenger belted and unbelted 5th percentile female Hybrid III dummy were studied. In each test mode, the Madymo Rigid Body dummies and the LSTC Rigid-FE dummies (beta release) were used. The CAE model results were compared with test results in both time history measurements (acceleration, velocity, displacement, forces, moments) and occupant kinematics (using high speed video). This is the result of one case study and the authors do not intend to draw any general conclusions as to which dummy model is better in relation to the other.

Introduction

Rigid body models for the Hybrid III dummy family have been in use for over 15 years. The CAL3D rigid dummy model was created in 1981[1]. The Hybrid III dummy was modeled with less than 30 rigid body segments. The mass inertia of each body was represented by the mass at its center of gravity, as well as moment of inertia about each of the three local axes. The joints for each body were modeled with kinematic constraints for the physical joint type designed for the dummy. For example, the knee joint was modeled as a hinge joint, the hip joint was modeled as a ball and socket joint and shoulder joint was modeled as a universal joint.

The Madymo 3D dummy model was announced in 1980[2]. This dummy model was also a rigid body type with kinematic constraints defined. Madymo become widely used later as a commercial CAE tool for occupant and restraint simulations.

As users became confident with Madymo dummy models, they felt the need to run the dummy model with FE vehicle interiors and/or vehicle structures. A Madymo and PAM-CRASH coupling application was reported in 1990[4]. Later, Madymo coupling with other codes such as LS-DYNA® became available.

As computing power increased, the need for full FE dummy models became apparent. A PAM-CRASH FE dummy model was reported in 1996[3]. An FE EUROSID model for PAM-CRASH was reported in 1992[5]. Later a 5th percentile female Hybrid III FTSS model was reported in 2000[6].

The use of dummy models was driven by regulatory and company internal requirements. The basic important dummy responses in pre-2003 FMVSS 208 regulations were head accelerations, HIC, Chest accelerations, Chest deflections and Femur loads. Other responses were also monitored. As more safety research was conducted and more field data became available, regulatory requirements were updated and new public domain safety rating tests were introduced. This meant that additional dummy responses were becoming more and more important for CAE tools to be able to correlate and predict. For example, the new FMVSS 208 requires Nij to be less than 1.0. This means that CAE Hybrid III dummy upper neck loads Fx, Fz and My responses are very important as we correlate our CAE models to tests. With IIHS frontal offset tests, tibia loads and tibia index have also become important CAE dummy model responses.

Methods

In order to compare dummy responses in a vehicle environment, belted and unbelted passenger frontal crash models were used. The reasons to select passenger models are for relative simplicity. With driver models, interactions between the airbag and steering wheel, steering wheel rim deformations, column rotation and stroke can all affect occupant responses. Since the main goal for this study is to study occupant channel responses in reaction with the seat belt and airbag, passenger frontal crashes present a more controlled environment than the driver side.

Unbelted crashes present dummy to airbag interactions while belted crashes present dummy to seat belt and dummy to airbag interactions. Both crash modes cover major FMVSS 208 requirements. Only rigid barrier crashes were studied in this paper. Frontal offset crashes and dummy model evaluation and comparison for lower legs is a subject for future study. For both the unbelted and belted crash modes, Hybrid III 5th percentile female and Hybrid III 50th percentile male dummies were used.

The vehicle interior was modeled with rigid elements in each model so that direct comparisons could be made. For knee to kneebolster contact, overall characteristic loading curves for each knee were specified. Barrier crash pulses were applied to the occupants. Also, crash test vehicle pitch and drop motion data were gathered and applied to the CAE models. With relatively small vehicle pitch motion, it was assumed that the model was a reasonable approximation in simulating the crash tests.

Data Filtering Discussions

Test data and CAE results need to be filtered so that they can be compared and analyzed. SAE J211 provides guidelines for filtering vehicle crash test data, including vehicle and dummy instrumentations. Since the source and the nature of noise for crash tests and CAE models are quite different, separate guidelines are needed for filtering CAE model results. The authors found that in most cases, lower filter classes such as CFC180 or CFC60 are needed for FE model outputs. There are exceptions; for example, in some cases, higher frequency data are part of the physical response. In those cases, users need to follow J211 guidelines. The CAE data presented in this paper are filtered per SAE J211 guidelines so that we can show the noise differences between test and CAE data.

Results

The dummy channel responses in all four test modes have been shown in the overlays that follow. Both test data and CAE data are filtered per SAE J211 guidelines. In the case of head accelerations, the acceleration components are filtered at CFC1000.

The dummy head accelerations for all tests and CAE are plotted in Figure 1.

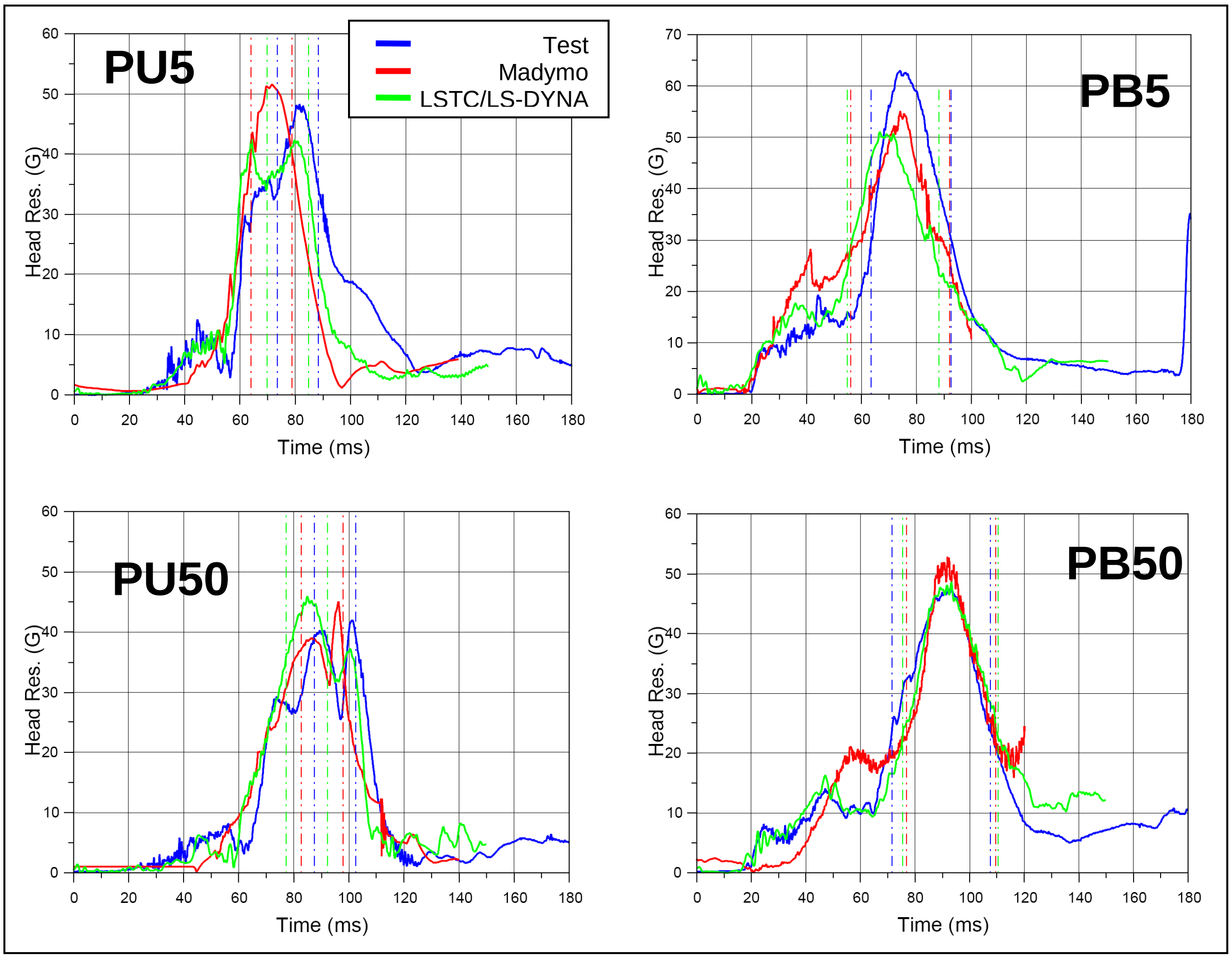

Figure 1 Head Acceleration Responses

The dummy chest accelerations for all tests and CAE are plotted in Figure 2. The LSTC model shows some oscillations in the PB5, the cause for which is currently unknown.

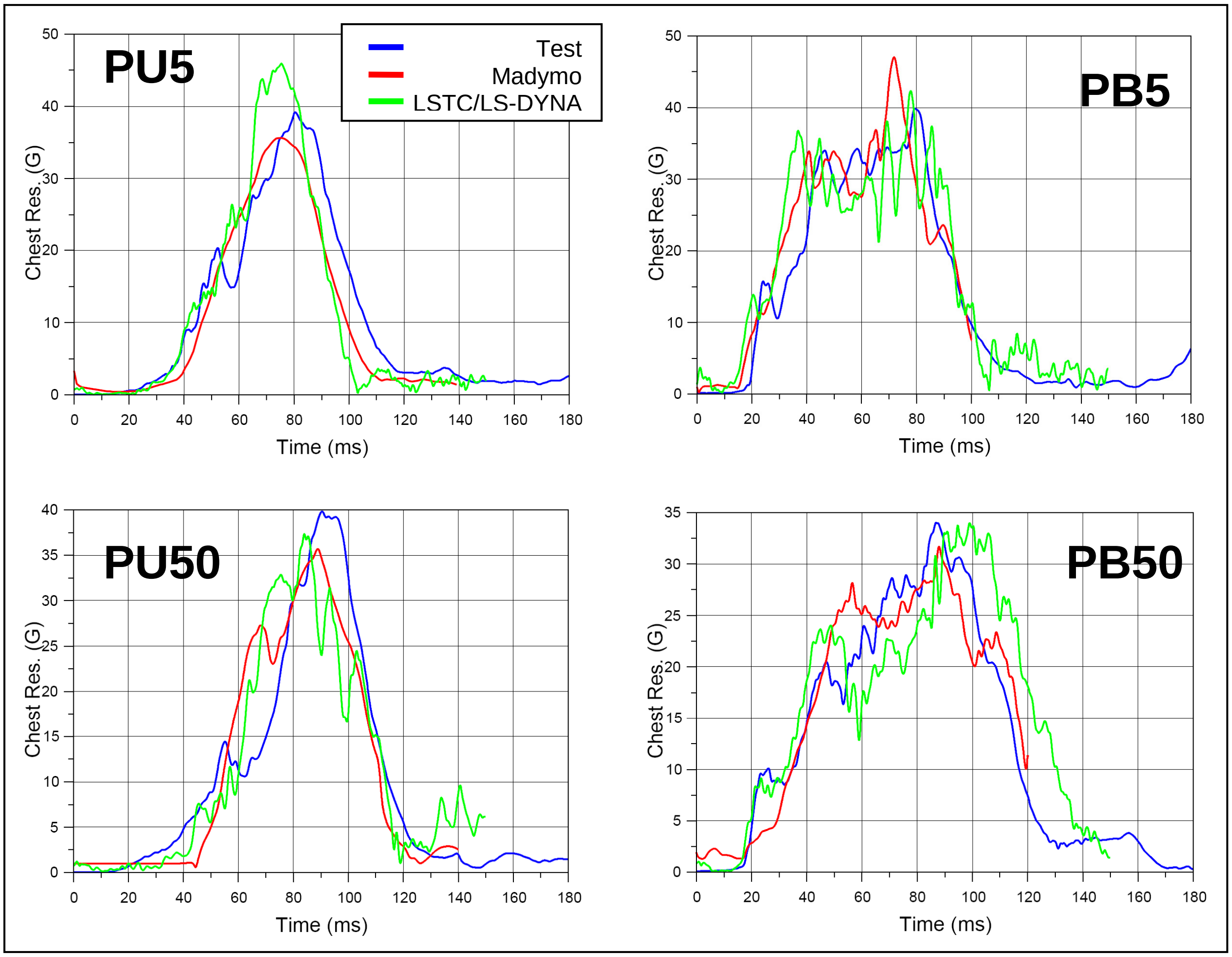

Figure 2 Chest Acceleration Responses

The dummy chest deflection responses have been the subject of much discussion for the occupant CAE community. While a lot of CAE models have reached good correlation for dummy chest calibration tests, dummy thorax loading in vehicle crash tests are quite different from thorax loading in dummy calibration test. The chest deflection for all tests and CAE are plotted in Figure 3. In all four cases the Madymo dummy model results show higher chest deflection compared to test and sometimes much higher as in the PU5 and PB50.

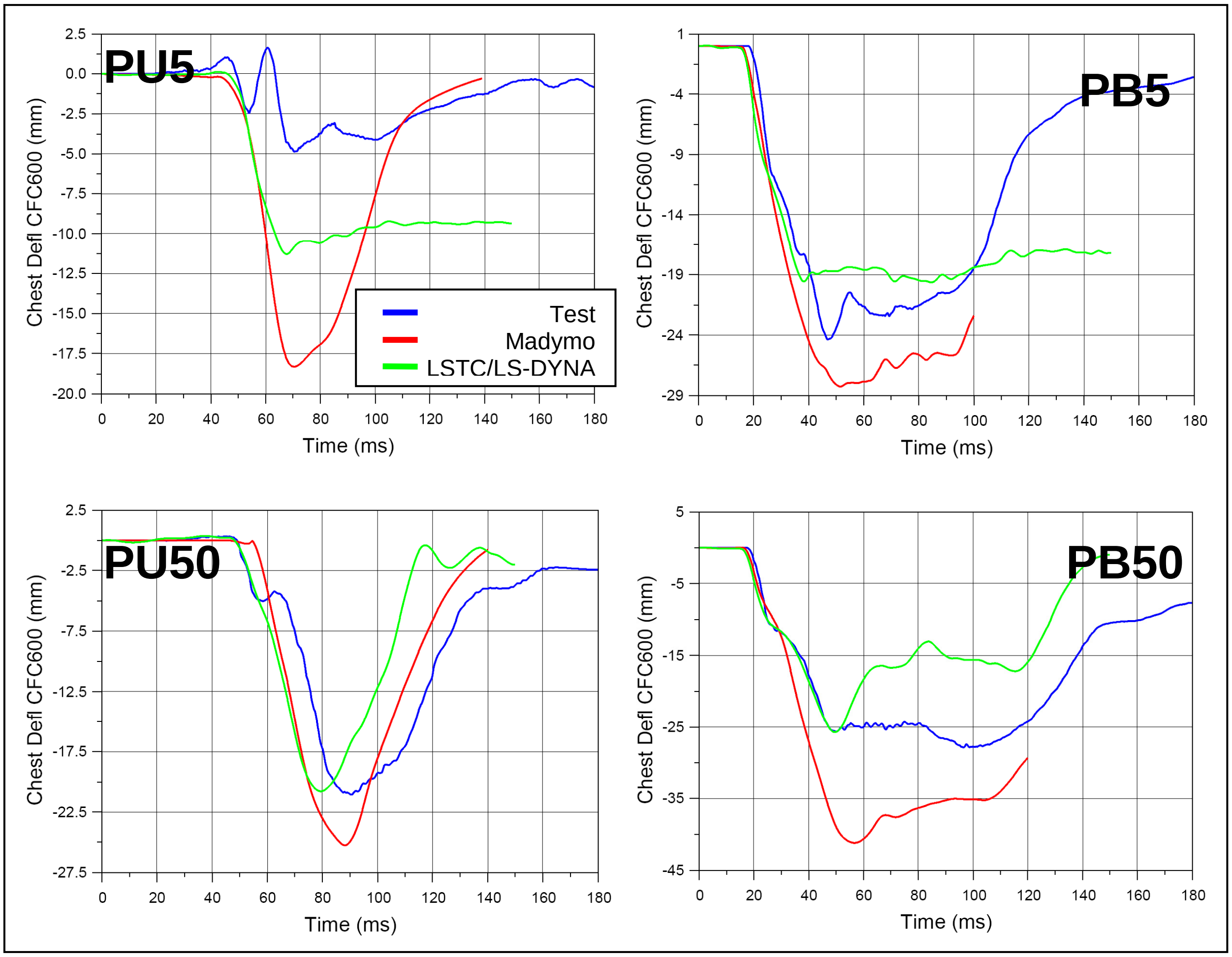

Figure 3 Chest Deflection Responses

Dummy upper neck load Fz are plotted in Figure 4. This moment is used in neck injury criteria (Nij) calculations. In the 50th belted case the Madymo responses match well with test in both shape and magnitude while the LSTC did relatively well in Unbelted 50th.

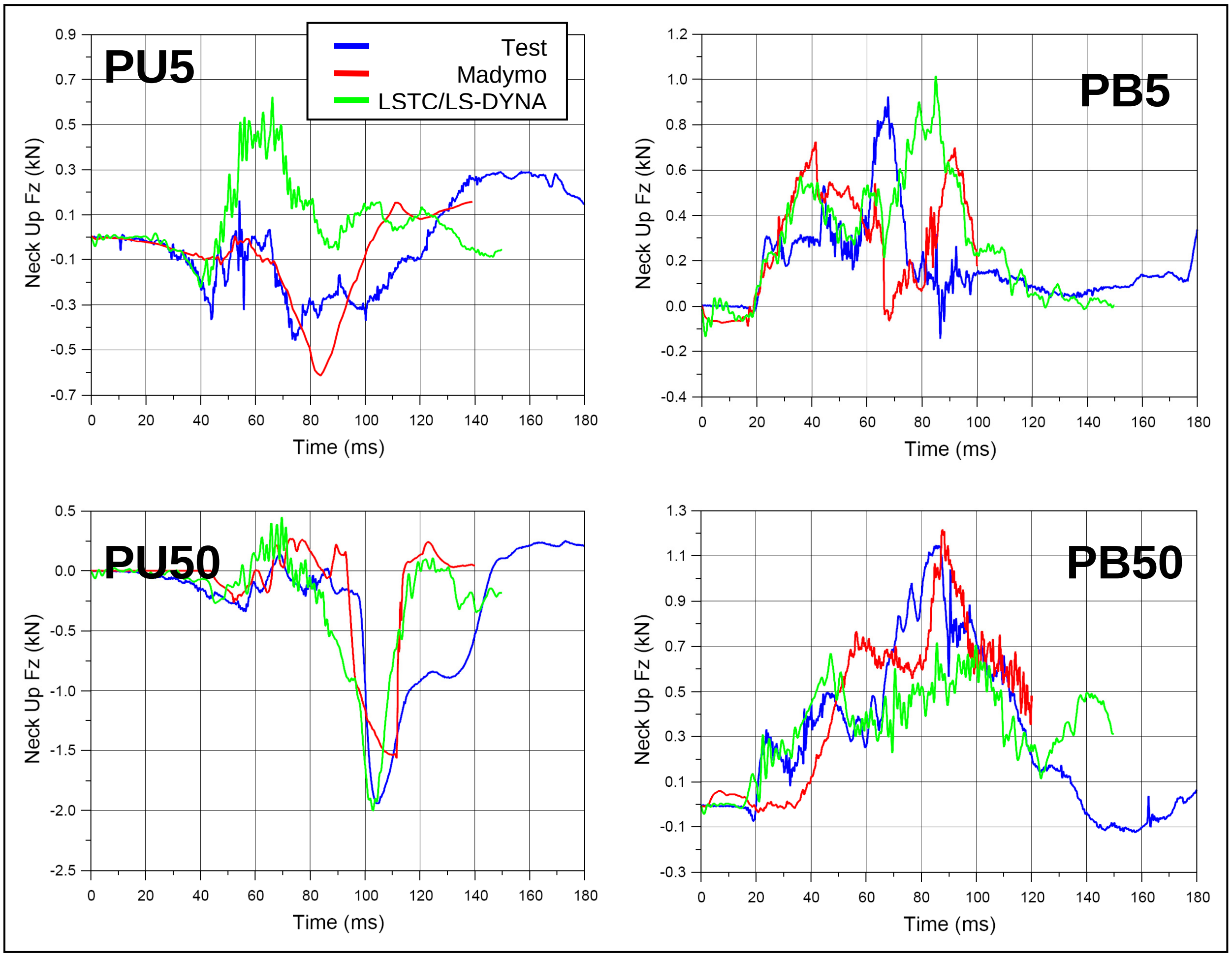

Figure 4 Upper Neck Fz

The upper neck moment My are plotted in Figure 5. This moment is used in neck injury criteria (Nij) calculations. The results plotted below have not been corrected by Fx for both tests and CAE results. Both CAE models for unbelted simulations correlate to tests pretty good.

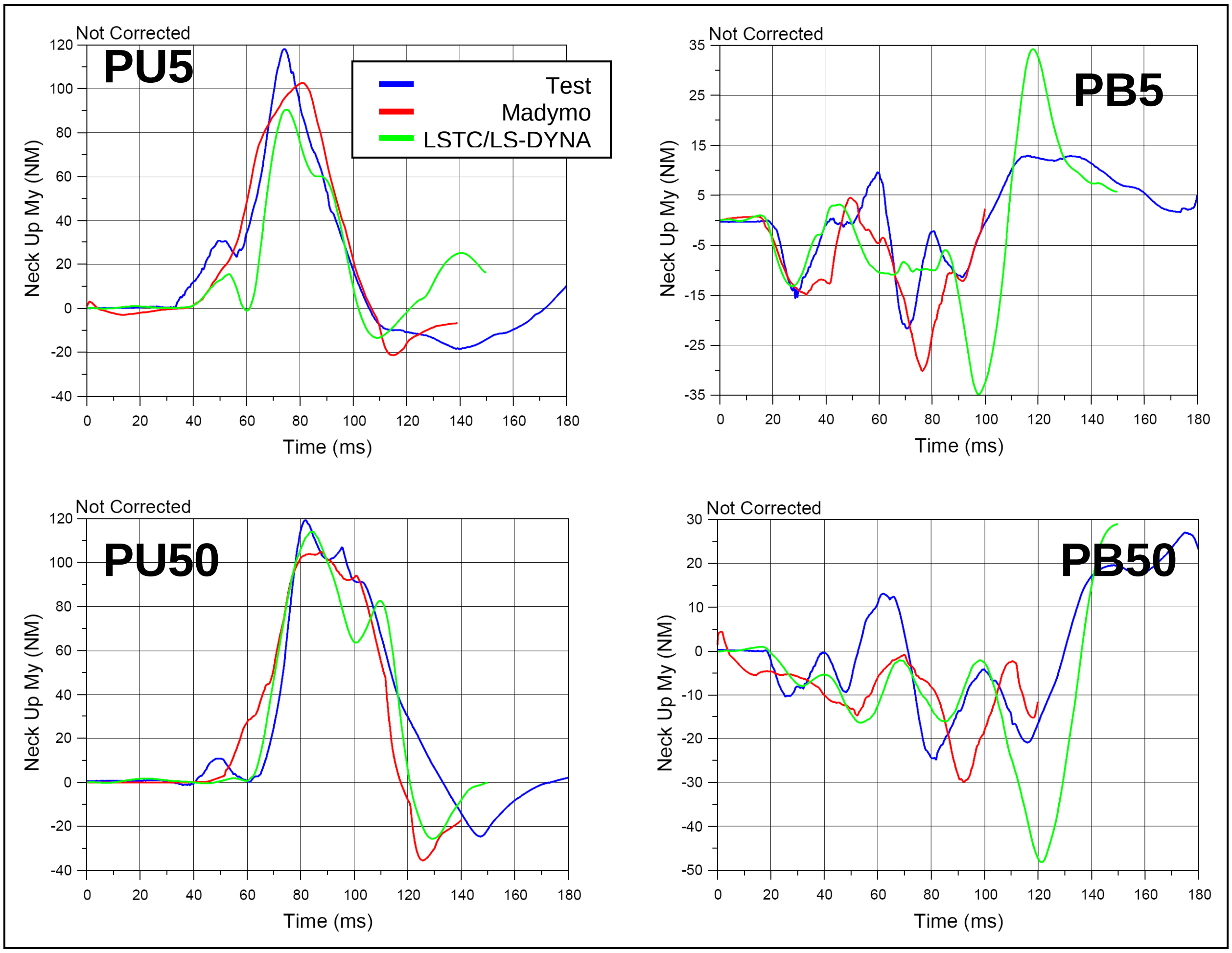

Figure 5 Upper Neck My

The upper neck shear force Fx are plotted in Figure 6. This shear force is used in calculating corrected upper neck moment My. For belted cases, the shear force Fx are much smaller in magnitude compared to the unbelted cases. Both CAE belted results show higher magnitude than test results.

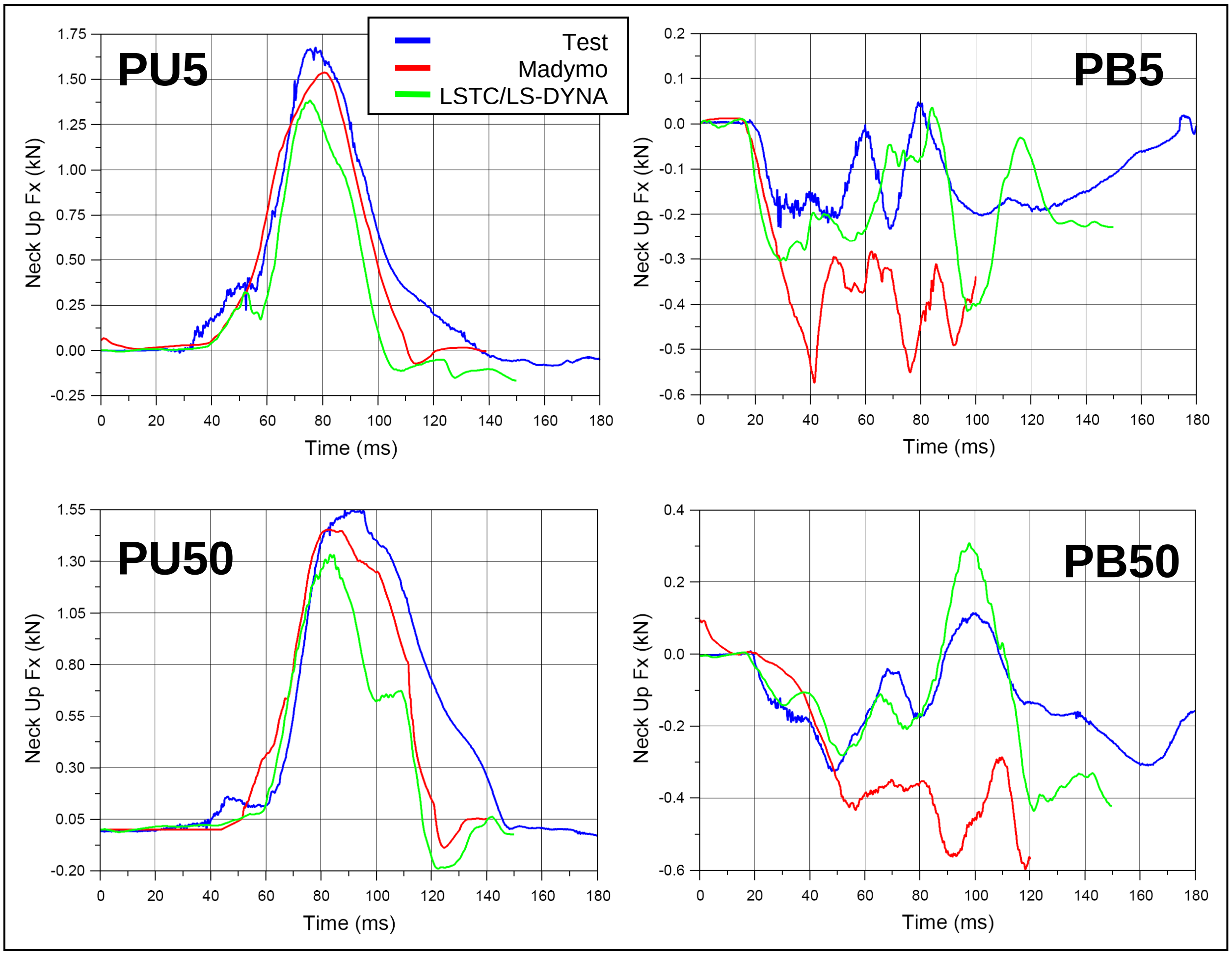

Figure 6 Upper Neck Fx

The upper neck Nij curves are plotted in Figure 7. The LSTC models have given some high peaks later on in the event in both belted cases. The magnitudes of Nij in the belted modes are significantly lower than requirement compared to the unbelted cases. In general for the unbelted modes, LSTC seems to have done somewhat better.

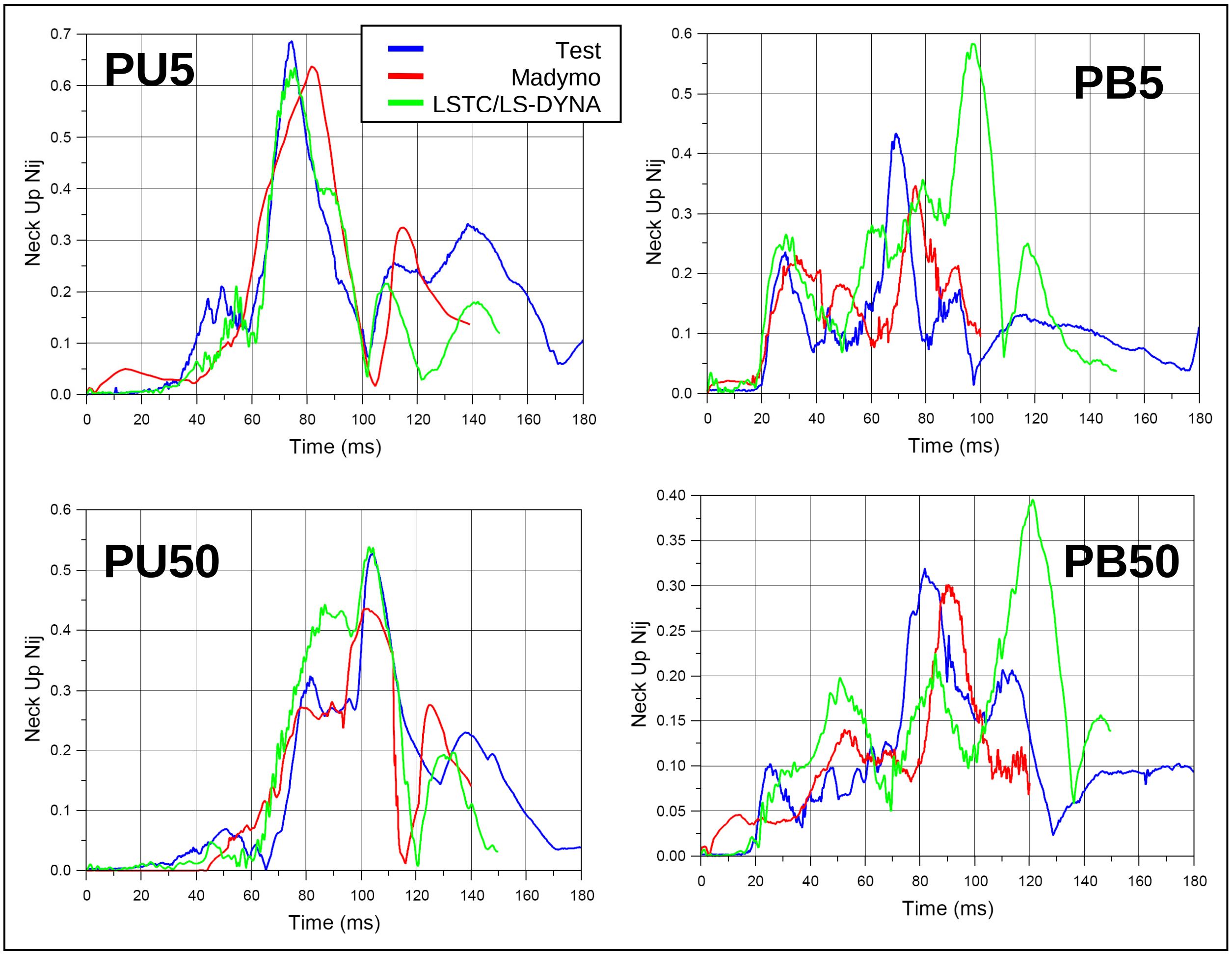

Figure 7 Upper Neck Nij

Conclusions

1. Neither Madymo nor LS-DYNA have proven themselves to be "consistently better" in all of the channel responses for every test mode. Sometimes Madymo seems to have done better while in some others the LSTC model has done better.
2. Setting-up of the vehicle environment models and the parameters contained within, have a lot to do with the final results. User experience is still important.
3. Both the Madymo and the LSTC dummy models have performed relatively well overall. They were both easy to position and use. Extraction of injury responses and general post-processing were also quite easy in either case.

Note: All these Madymo and LSTC models took less than 25-minutes to run in any test mode (Desktop 2-cpus). The LS-DYNA runs take somewhat longer in belted modes because of lower time-step requirement, caused by belt-slippage at D-Ring and Buckle.

Abbreviations

PU5	Passenger unbelted test with 5th percentile female dummy
PB5	Passenger belted test with 5th percentile female dummy
PU50	Passenger unbelted test with 50th percentile male dummy
PB50	Passenger belted test with 50th percentile male dummy
CAE	Computer Aided Engineering
DOE	Design of Experiments
FTSS	First Technology Safety Systems (www.ftss.com)
Madymo	MAthematical DYnamic MOdel, by TASS (www.tass-safe.com)
Nij	Neck Injury Criteria
LSTC	Livermore Software Technology Corp. (www.lstc.com)
LS-DYNA®	Software by LSTC
FE	Finite Element
CAL3D	Software funded by NHTSA, originally developed by CALSPAN
SAE	Society for Automotive Engineers (www.sae.org)

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