Side Impact Occupant Modeling Practices in Comparison to Test Results

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Abstract

A methodology to obtain and estimate the second row dummy response during the FMVSS 214 Barrier Side Impact test is described. Because of the limited amount of space between the occupant and the car structure, it is challenging to manage and predict the energy distribution in the FMVSS 214 crash mode. Increasing use of Finite Element models provides an edge in product development and its use is increasing as development time is reducing. For increased correlation with the test and more realistic dummy response, several factors are important, including the effect of restraint systems and representation of interacting components. This paper describes a methodology by which the second row occupant injury can be well-correlated to the test and used to help enhance occupant protection during vehicle development. A commercially available SID-IIs dummy and a Moving Deformable Barrier from LSTC are used in this study.

1. Introduction

In today's automotive world, most manufacturers use CAE analysis techniques to speed-up product development and gain confidence for test evaluations. Thus, proper modeling of a finite element model can be useful to get a reasonable forecast of the overall performance of the vehicle and its occupants. Because NHTSA has a combined overall star rating for the front, side, and rollover test modes of a vehicle, it's more challenging than ever to achieve 5-star performance. This makes it even more important for the CAE analysis techniques to be accurate.

From an overall star rating standpoint, the effect of one design change for a particular mode on other modes can be judged using CAE tools. There are practical limits to time and availability of vehicles to test for every mode for every design change made to the vehicle. Since CAE tools can provide information for decision-making, engineers increasingly use results from CAE analysis during product development.

Accuracy of a CAE tool is as important as using it correctly. Correct representation of the components and ensuring accurate modeling techniques for the assemblies is important. Representing components and their interactions in CAE is an evolving state of the art. The more we learn from our experience and understand the complex behavior of the actual system, the more useful CAE tools become. Accurate representation of the intricate parts, corresponding material properties for different modes, and the relative effect on the performance of the subcomponents all play a role. Within CAE groups, there are defined internal modeling techniques dependent on previous experience and internal factors, such as the expected accuracy from the CAE model for decision-making, available computing power, total model size, and turnaround time. This paper aims to discuss the effect of modeling seatbelts, door components, and the seat armrest design on the injury of the 2nd Row Occupant during a side impact with a moving deformable barrier (MDB).

2. Dummy seatbelt routing

Commercial finite element dummies are available for predicting occupant injuries in LS-DYNA®. The current study uses the FTSS SID-IIs ver3.0 dummy for LS-DYNA. FTSS dummy model has load cells at various dummy locations, such as head, shoulder, ribs, pelvis, and upper and lower extremities. Values from these load cells are measured and compared to the corresponding test values to check the level of correlation. The dummy position with respect to barrier is important. A proper seat foam compression is also important so that the dummy location is matched with the test dummy position in the X, Y and Z coordinates. Components of the passenger restraint system, such as the seat belt tension and the routing of the seatbelt, are vital to help keep the dummy in position during an impact. For this study, the seatbelts were modeled with a combination of 4-noded shell elements and 1D seatbelt elements passing through a slip-ring. This representation is to allow for the variation in length between the lap and shoulder belts during impact. Figure 1 shows the difference in dummy positions with and without a properly-modeled restraint system.

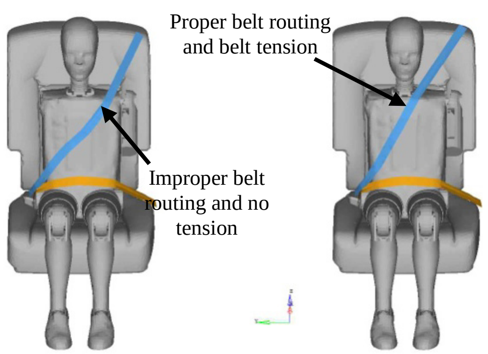

Fig. 1a. Pre-Impact Seatbelt Routing.

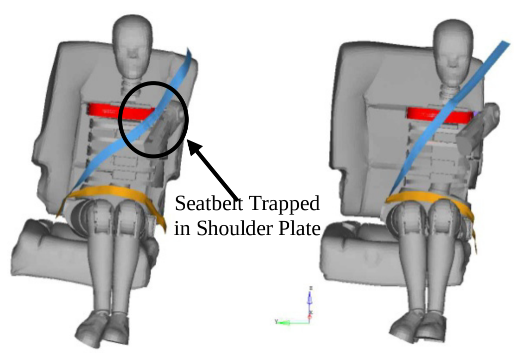

Fig. 1b. Post-Impact Seatbelt Routing.

Fig. 1. Proper/Improper Shoulder Seatbelt Routing

To obtain realistic occupant kinematics, it is crucial to accurately model proper pretension and routing for the shoulder seatbelt. Figure 1a compares a seatbelt that is routed and tensioned improperly and properly across the dummy. As shown in figure 1b, improper routing and tensioning causes the seatbelt to become trapped in the shoulder plate, which causes the dummy to move inward and away from the impact area. This kind of improper modeling could easily lead to incorrect understanding of the dummy kinematics and interaction with the adjoining door components, which in turn could yield different injury predictions.

Likewise, tension and routing of the lap belts is equally important. Improper tension can cause the dummy to rise up considerably from the seat cushion and have a higher point of impact on the door liner in the test. This could lead to unrealistic load transfer in the dummy pelvis, resulting in inaccurate injury values. As shown in figure 2a dummy with an improper belt routing and tensioning (left) is able to rise out of the seat, which yields little pelvis load as evidenced by the lack of pelvis plug deformation. Conversely, a dummy with proper belt routing and tensioning (right) is held lower in the seat, which yields higher pelvic loads as evidenced by a substantial amount of pelvis plug deformation.

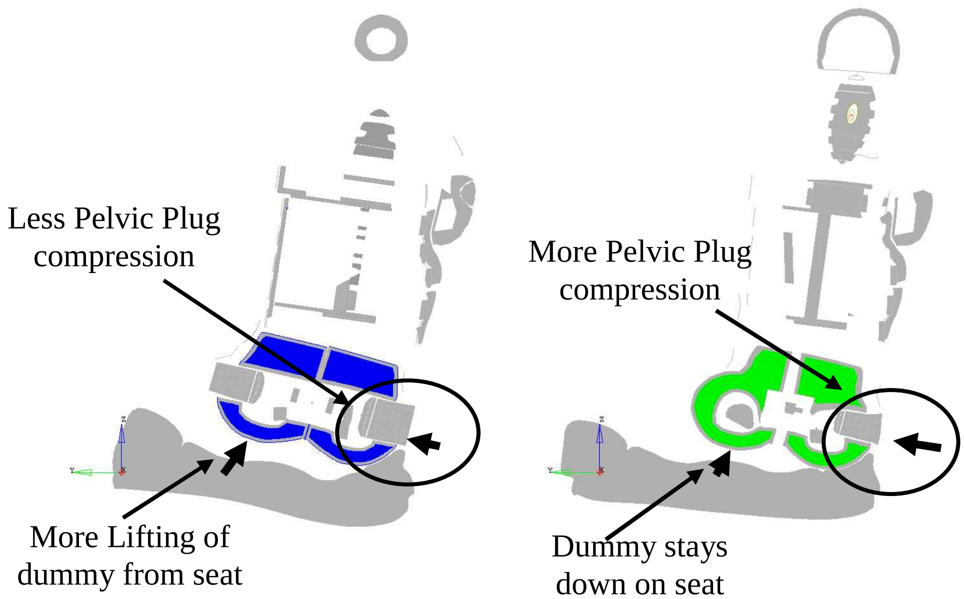

Fig. 2. Effect of Lap belt routing and pretensioning.

Figure 3 shows the door components that have an effect on the door intrusion and occupant response.

3. Door Components

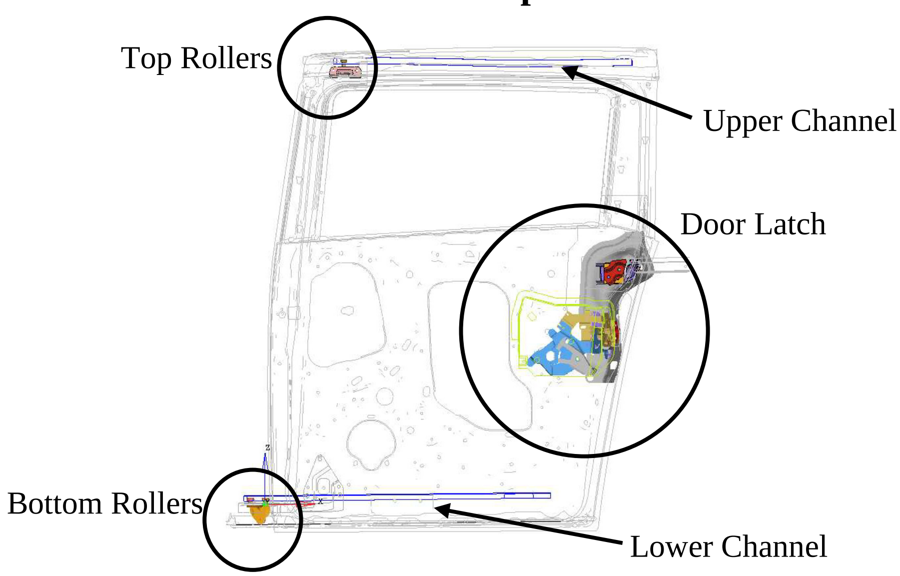

Fig. 3. Door Components Considered

Initially, the door rollers were represented by rigid spiders in LS-DYNA (*CONSTRAINED_NODAL RIGID_BODY) (see figure 4a). This rigid representation was later refined by modeling the actual circular rollers (see figure 4b) with a rigid material representation and put in contact with the body. The rollers were free to move in the C-channels and no additional constraints were applied. When the results from these two analyses were compared, a significant difference in the door intrusion and kinematics was observed.

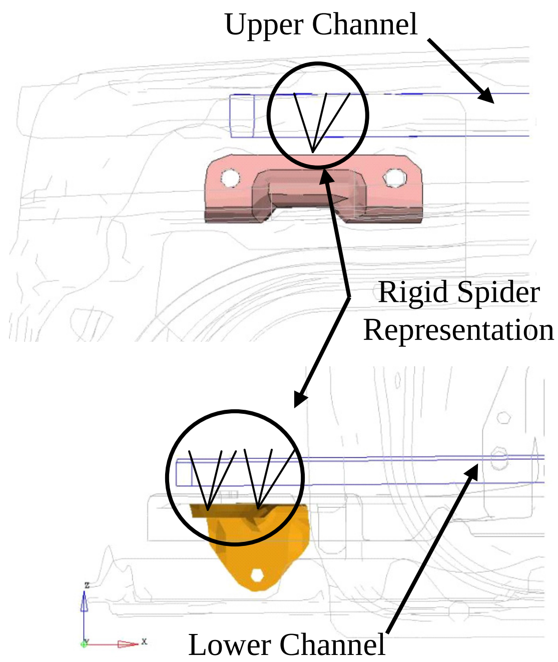

Fig. 4a. Representation w/Rigid Spiders

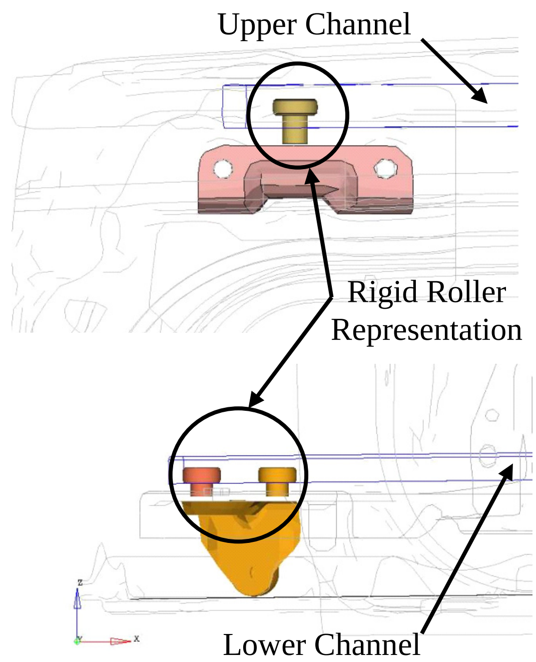

Fig. 4b. Representation w/Rigid Rollers

As shown in figure 5, the door latch was initially modeled with 4-noded shell elements with rigid connections to the door. This representation was also refined with solid elements for the latch locking mechanism. It was thought that the plastic latch cover, the primary function of which is to keep dust and water out of the latch assembly, would not make a significant impact on the occupant injuries. When the results from two simulations were compared, it was determined that this premise was not true. The area near the latch cover did not crush during the test, and translates into the passenger compartment and towards the occupant, resulting in higher injury potential. The effect of refining these components on the occupant peak injury is shown in figure 6.

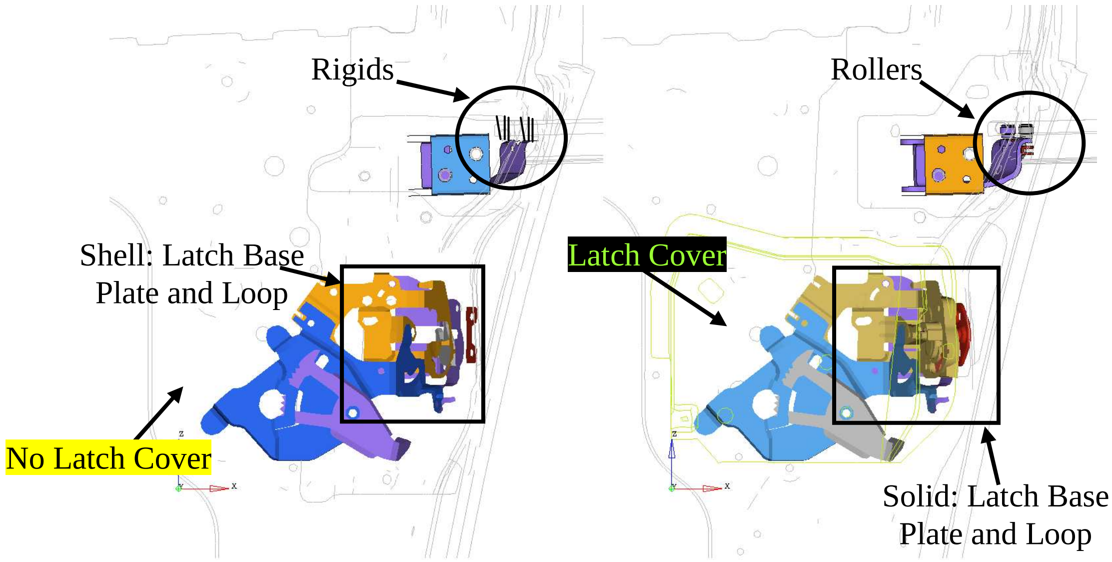

Fig. 5. Door Latch

Figure 6 shows how modeling the door components differently affects occupant injury values. The first two upper ribs appear to be less sensitive to the model changes than the third upper and the bottom lower ribs. The difference in rib deflection is caused by a change in the structure/occupant interaction and occupant kinematics due to the modeling of the additional components. Thus a proper representation is crucial to get a more realistic picture of actual test performance. This information can later be used to analyze and address predicted concerns in the appropriate area and to help control the rib injury, if required.

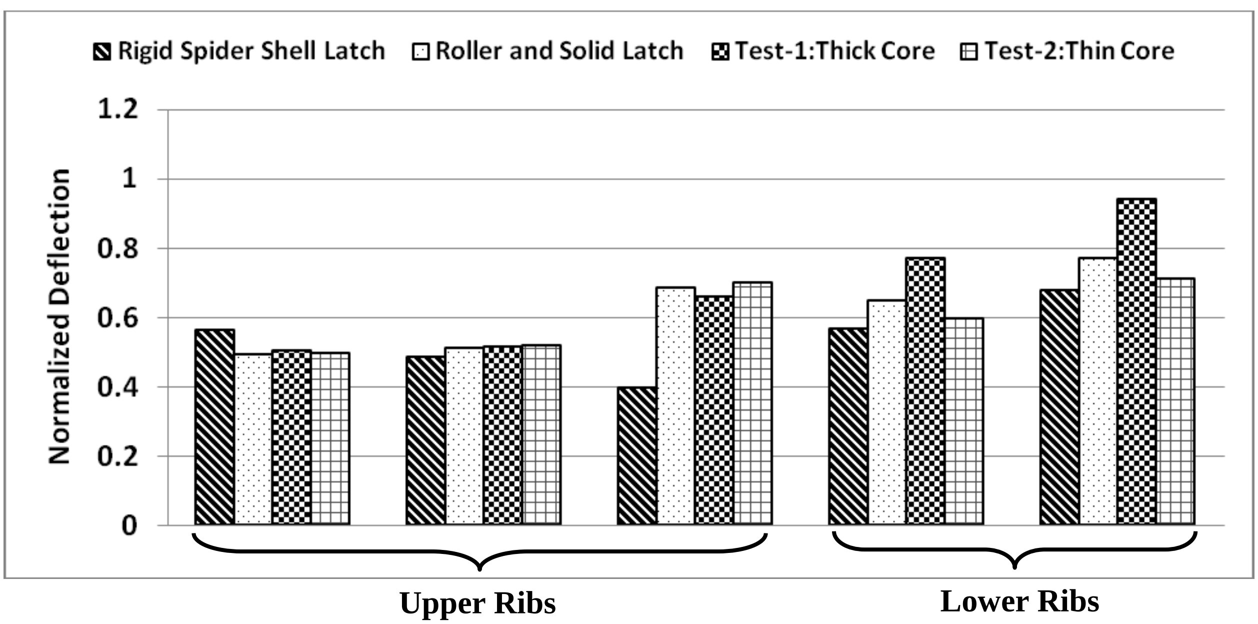

Fig. 6. Change in Occupant Response

As shown in figure 7, when overlaying the door panel deformations, there is significant change in the door characteristics. When Rep1 of the latch (rigid spider) is used, the top of the door (left) does not intrude as much as when Rep2 of the latch (rigid circular rollers) is used. Because of the latch cover stiffness, the door panel at the occupant's lower ribs location intrudes more, which could result in more severe occupant injuries.

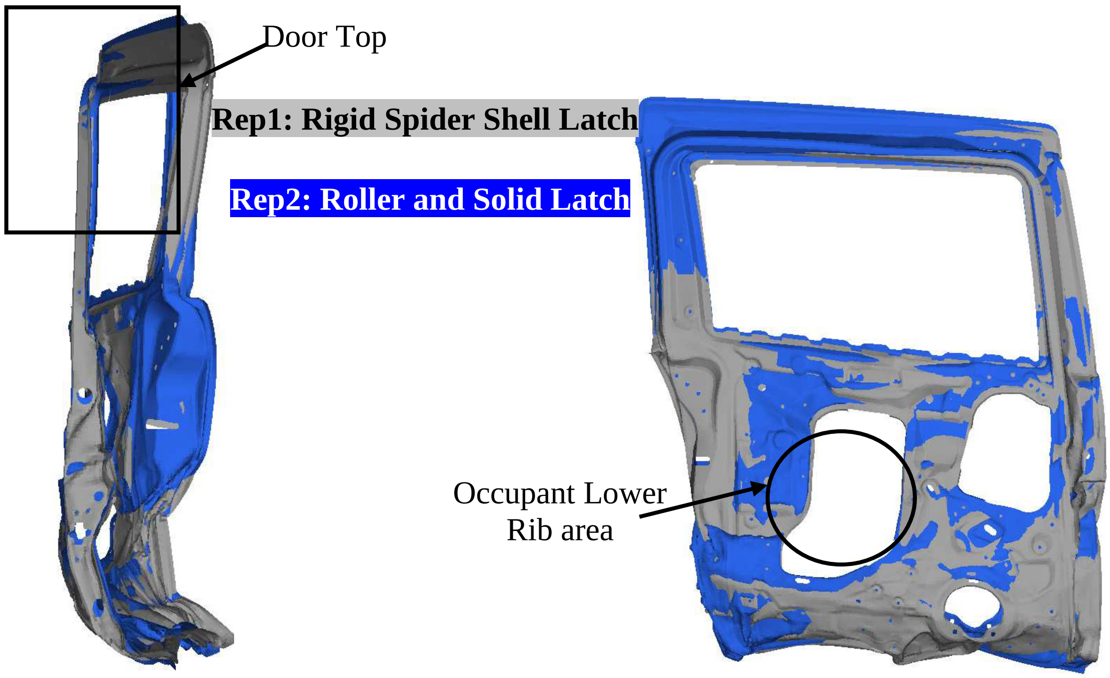

Fig. 7. Door Panel Deformation Overlay

The difference in the door panel deformation can also be attributed to the relative displacement of the top and bottom rollers. As shown in figure 8a (right), when modeled more realistically, the top roller slides in the C-channel without any resistance. If the rigid representation is used, the relative distance between the roller and the channel is fixed. This added constraint will cause some resistance to the inward door motion as shown in figure 8a (left). Similar behavior is observed for the bottom rollers as well when modeled realistically as rigid components (see figure 8b).

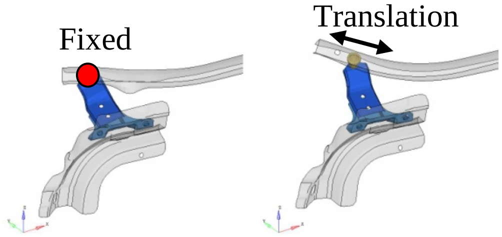

Fig. 8a. Top Rollers

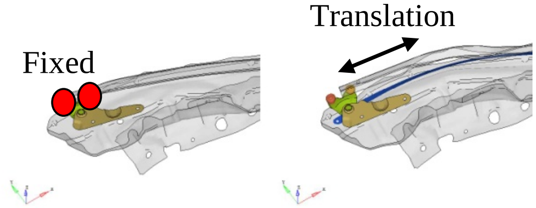

Fig. 8b. Bottom Rollers

4. Seat Armrest

Figure 9 (center) shows the construction detail of the 2nd row seat armrest. The armrest can be divided into two components: the outer armrest foam and the inner armrest core. The foam provides comfort to the occupant while the core provides the required strength to perform day-to-day function and operation. When a moving deformable barrier impacts the vehicle during a crash test, the armrest may move toward the occupant and interact with the occupant. As shown in figure 9, the armrest foam will deform and absorb some of the energy before contacting the occupant's lower abdomen area; however, since the core is strong, it has the potential to cause injury. Hence, modeling the correct stiffness of the armrest assembly plays a part in accurately predicting occupant injury assessment reference values.

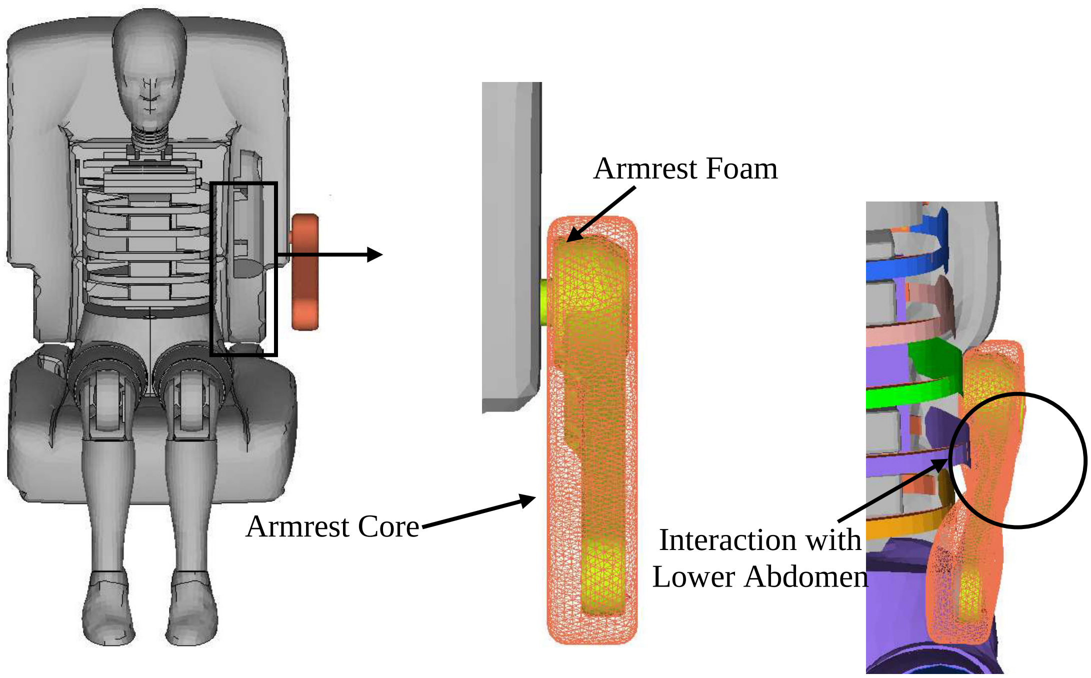

Fig. 9. Seat Armrest details

As shown in figure 10, the model was used to estimate the effect that thinning the armrest core might have on reducing the potential for injury to the occupant's abdomen ribs.

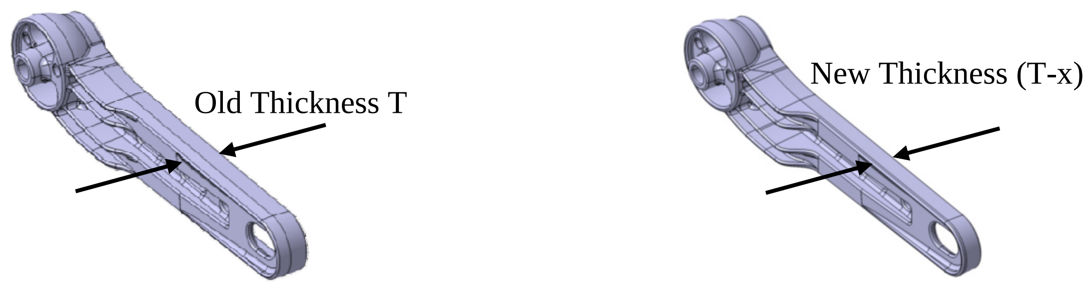

Fig. 10. Old (thick) and New (thin) Armrest Cores

As shown in figure 11, abdomen rib deflection was loosely coupled to the armrest core thickness. Thinning the core reduced the interaction of the armrest with the occupant. CAE predicted a 3% reduction in the Abdomen Rib-1 injury, yet the test yielded a significantly higher reduction of 18%. The correlation of the CAE prediction of Abdomen Rib2 was better with CAE predicting a 14% decrease and the test yielding an 18% decrease.

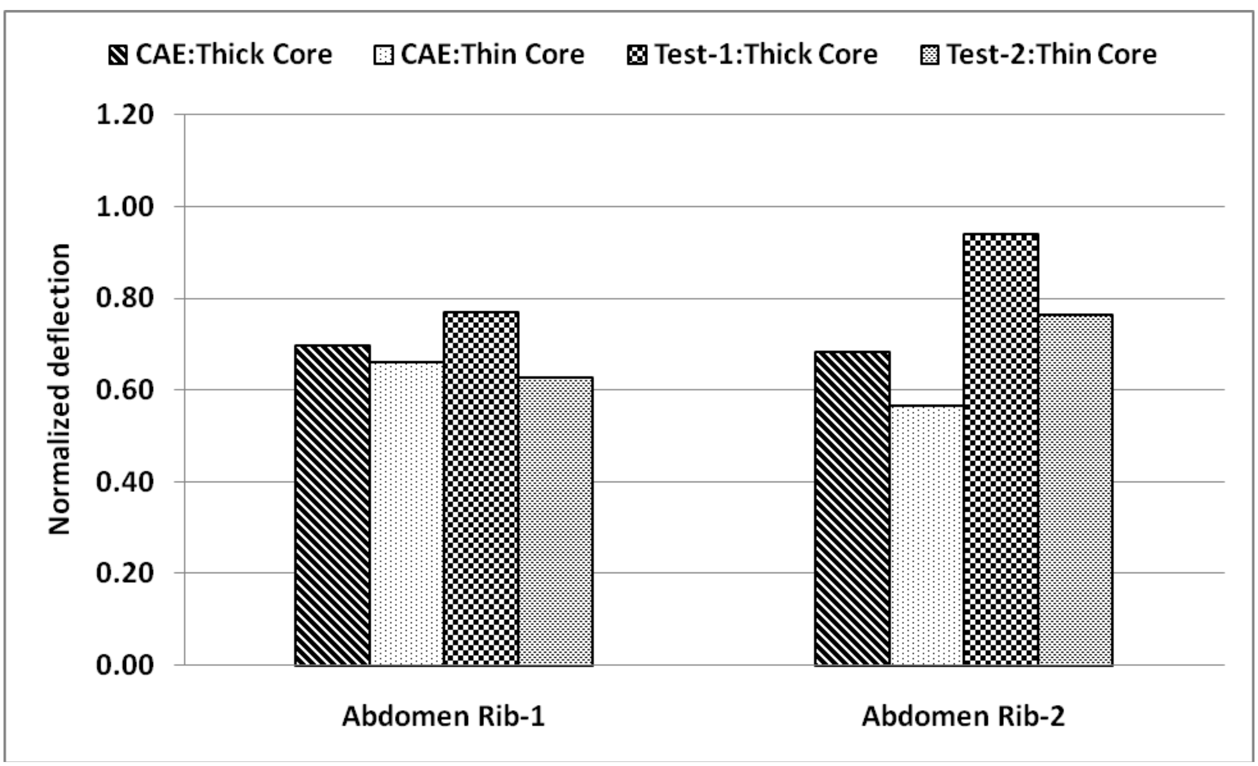

Fig. 11. Effect of Armrest Core Thickness on Occupant injury

5. Conclusion

1) Obtaining accurate occupant kinematics and injury prediction depends largely on proper modeling of the restraint system (seatbelts) and corresponding dummy seating position.

2) Realistic behavior and interaction of the sub-assemblies among themselves and with the occupant can lead to better injury prediction and can help to create effective design changes with which to control occupant injury.

3) The results obtained from CAE analysis still depend heavily on user experience and a company's standard operating procedures.

6. References

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