Simulation and Validation of FMVSS 207/210 Using LS-DYNA

Vikas Patwardhan
Tuhin Halder
Frank Xu
Babushankar Sambamoorthy

Lear Corporation
21557 Telegraph Road
Southfield, MI 48034 USA

Email: vpatwardhan@lear.com
(248) 447 1958

Keywords: FMVSS 207/210, Quasi-Static, Automotive Seat

ABSTRACT

Federal Motor Vehicle Safety Standard 207 and 210 applies to automotive seats, their attachment assemblies, and seat belt anchorage assemblies. These regulations ensure their proper location for effective occupant restraint, and it also minimizes the possibility of anchorage failure due to the forces resulting from a vehicle crash.

These requirements are the most critical in seat development process and are generally considered the benchmark for an automotive seat's safety performance. Finite Element Analysis (FEA) is widely used to simulate the FMVSS 207/210 on a component level as well as on a complete seat system level. Quasi-static simulation using LSDYNA is one of the chosen methods to simulate the requirement. This paper will discuss a simple but accurate method to simulate and validate the FMVSS 207/210 test. The methodology describes the use of lighter body blocks to reduce the dynamic effect, simpler seat belt formulations, and the right use of element formulations and contact interfaces.

INTRODUCTION

Vehicle interiors are one of the fastest changing segments in the automotive industry. Seat design is becoming more demanding and challenging because the Original Equipment Manufacturers (OEMs), driven by competition and customer needs, are asking for more complicated functions. Features like kneel-fold, tumble, detach, stadium seating etc. are available in most of the vehicles and the industry wants all these without compromising the weight and safety. Seats are designed to meet various loading conditions like forward and rearward dynamic loads, ISOFIX loads as per the new FMVSS 225 requirements, and other static loads.

One of the most severe loading condition that a seat has to withstand is the FMVSS 207/210[1] requirement. These standards apply to seats, their attachment assemblies, and seat belt anchorage assembly and are to ensure their proper location for effective occupant restraint and minimize the possibility of their failure by forces acting on them as a result of vehicle impact. United Nations regulation ECE14[2], similar to 207/210, restricts the forward displacement of retractors beyond the H-point of the seat system.

APPROACH

Physical Test Set Up

The actual test set up consists of two load application devices called the body blocks. The body blocks consist of a shoulder block shown in Figure 1, which represents the chest of an occupant. Figure 2 shows the lap block, which represents the torso of an occupant. A high strength seatbelt wraps around the shoulder and the body block to hold them in place and to attach them to the seatbelt anchor points.

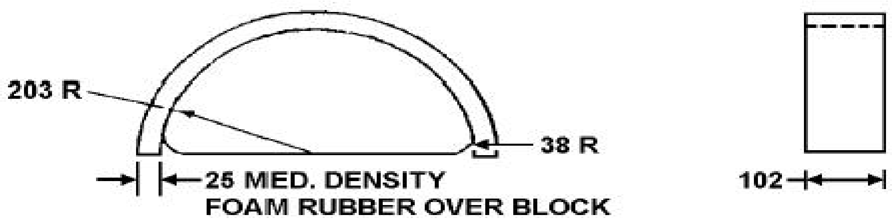

Figure 1. Dimensions of a Shoulder Block

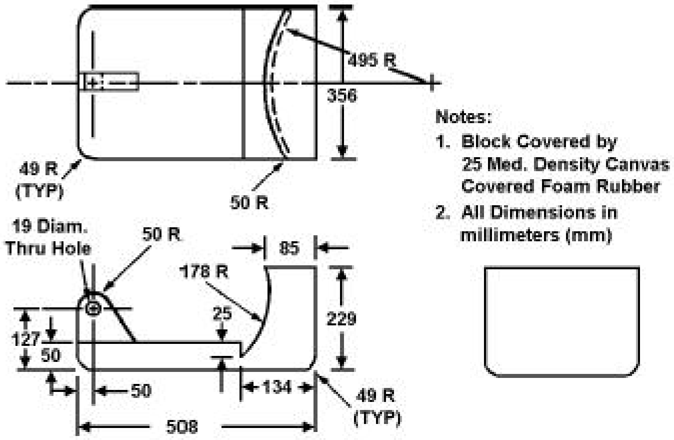

Figure 2. Dimensions of a Lap Block

The blocks are tied to pull chains and the pull chains together with the hydraulic cylinders apply load to the body blocks. The load is at 5 to 15 degrees to the horizontal. A rigid bar is welded to the seatback at the center of gravity location of the seat system, to apply a static load, equivalent to the seat inertia during crash. A force of 13345N +15 % (3000lbf +15%) is applied on each of the body blocks and 23 times the weight of the seat system is applied to the rigid bar. All the loads are applied in 30 sec and held for 10 sec. The seat should be adjusted to the rearmost position for horizontal travel (if it has tracks), full down position for vertical travel (if it has height adjusters) and the seat back should be reclined to the design position.

Figure 3. Physical Test Setup

Finite Element Model Setup

The FE model for the 207/210 analysis consists of a seat structure, body blocks, and seatbelts as shown in Figure 4. Most of the seat structure is made up of metal stampings and tubes and is modeled using shell elements. Critical latches and strikers are modeled as solid elements[3]. Bolts and rivets that attach the different parts of the seat assembly were modeled using beam elements. Washers were used with the bolts at the attachment locations and modeled for accurate stress and strain levels[4]. Pivoting action of a bolt or joint was simulated by a regular beam element with a very low value of torsional rigidity. The lap and the shoulder blocks were modeled using shell elements and rigid material property was assigned to them. The part of the seatbelt that wraps around and comes in contact with the body blocks was modeled using 2-D shell elements. The rest of the seatbelt length was modeled using 1-D seat-belt elements. Pull chains were also modeled as 1-D elements.

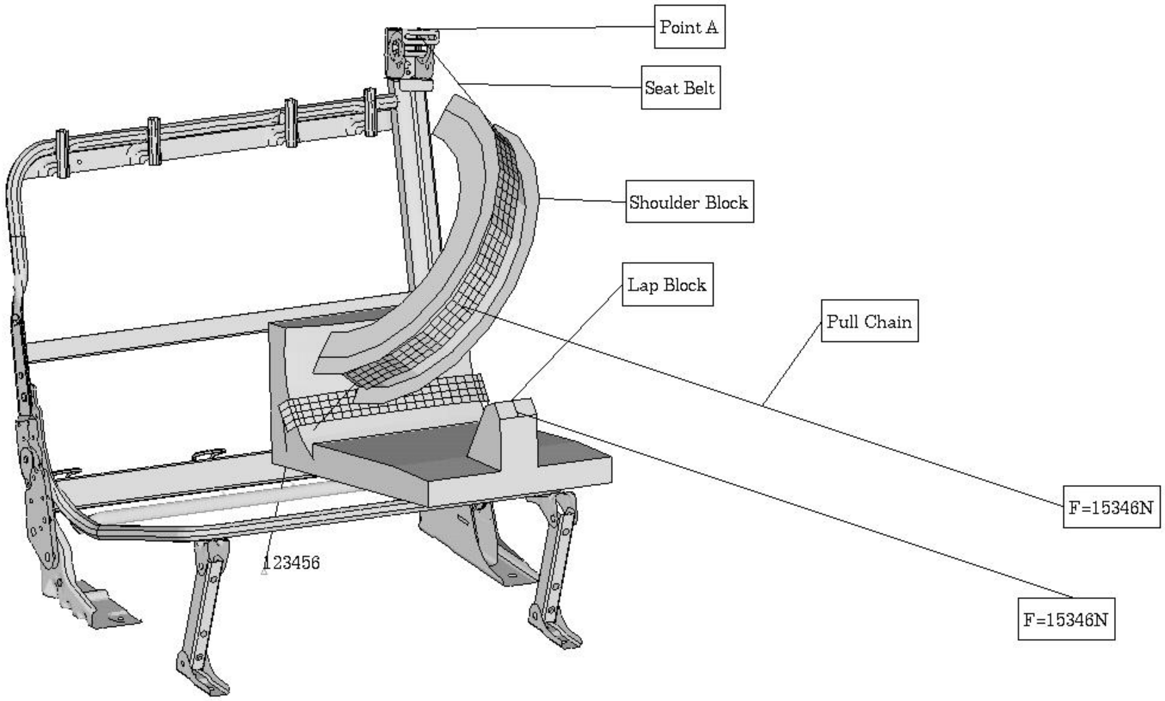

Figure 4. FE Seat Model

*CONTACT_AUTOMATIC_SINGLE_SURFACE was used to define contact for all the parts that interact with one another[5]. The loads were applied at the end of, each of the pull chains, which in turn loaded the seat through the body blocks. The static load in the physical test was simulated as a quasi-static load using LS-DYNA[6]. The total load was attained in a period of 60ms and then held for 10ms [7], as shown in Figure 5. During the physical test, cushion foam is completely compressed during the pre-load, hence the foam was not modeled in the FE analysis.

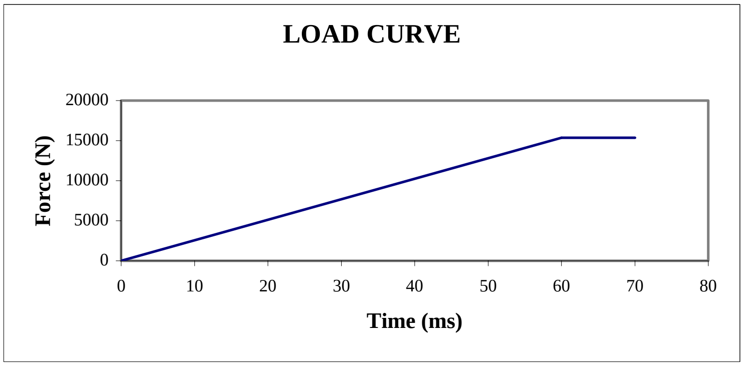

Figure 5. Load Curve for FE Analysis

Baseline Simulation

FE simulation of the 207/210 test was performed to establish the baseline model. Detailed analysis of the results showed couple of interesting observations. Since the cushion foam was not modeled , the lap block was not supported in the vehicle X-Y plane. It was observed that the lap block rotated about the vehicle Y-axis. Also, the dynamic effect due to quasi-static loading imparted a higher load to the structure. The 2-D seatbelt elements exhibited high hourglass energy and the energy ratio, Total Energy/Initial Energy, was unreasonably low. In order to validate the FE model, the parameters discussed above were incorporated into a design of experiments (DOE).

Design of Experiments

The four different parameters studied in the DOE were:

1) Mass of body blocks
2) Constraints on the body blocks
3) 2D seatbelt element formulation
4) 1D seatbelt property.

Five different cases were simulated, and in each of the cases, the model parameters were varied to study the effect of each one of them. Table 1 shows the combination of different parameters in each of the five cases.

Table 1. Design of Experiments

Iterations	Test Body Blocks: 3.15 Kg	FE Body Blocks: 0.4 Kg	Body Blocks: No Constraints	Body Blocks: Constrained	2D Seat Belt: Element Formulation 16	2D Seat Belt: Element Formulation 9	1-D Seat Belt Properties: Actual	1D Seat Belt Properties: Modified
Case1	X		X		X		X	
Case2		X	X		X		X	
Case3		X		X	X		X	
Case4		X		X		X	X	
Case5		X		X		X		X

Mass of Body Blocks

The mass of the blocks was the first parameter that was varied between Case1 and Case2. The difference between the body blocks used in the physical test and the modified body blocks was studied. From Figure 6, it can be observed that, in Case2 the total kinetic energy is lower than in Case1. The kinetic energy drops and stabilizes as soon as the initial seatbelt slack is removed. Displacement of Point A, as shown in Figure 4, was chosen as reference for displacement correlation. Due to the reduced inertial effect of the lighter blocks, the seat displacement at Point A was lower in Case2 than in Case1. Hence, as seen in Table 2, lowering the mass of the blocks has an impact on the displacement results also.

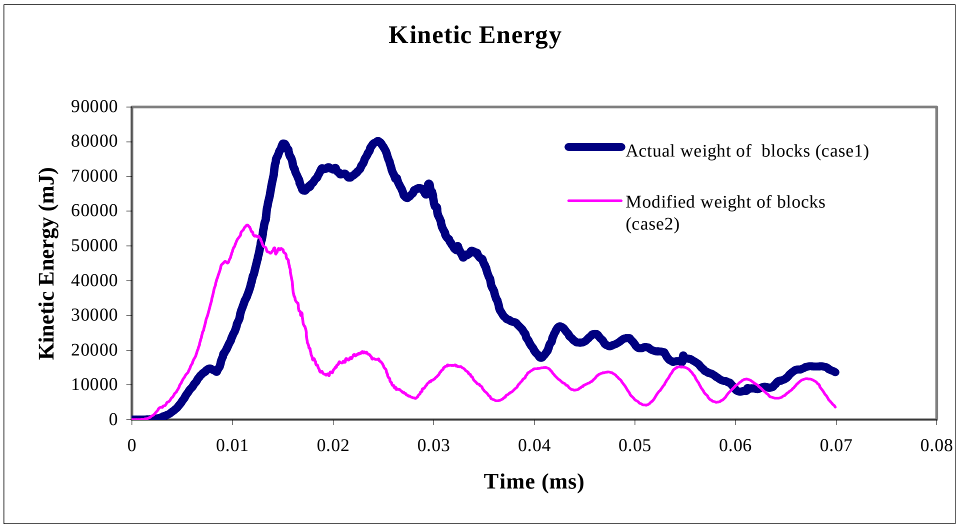

Figure 6. Kinetic Energy of the Body Blocks

Table 2. Displacement of Point A for Case1 and Case2

Iteration	Mass of Blocks	X Displacement of Point A
Case1	3.15 Kg	281 mm
Case2	0.4 Kg	268 mm

Constraints on the loading blocks

The second parameter studied was the constraint on the body blocks. Between Case2 and Case3, the only difference was the degrees of freedom of the blocks. In Case3, the blocks were allowed to translate only in the direction of the load application. Table 3 tabulates the displacement of Point A for Case2 and Case3. It can be easily concluded that the displacement for Case3 is much closer to the physical test. In essence, changing the constraints of the body blocks and preventing their rotation influences displacement values.

Table 3. Comparison of Displacement for Case2 and Case3

Iteration	Physical Test Displacement of Point A	X Displacement of Point A
Case2	254 mm	268 mm
Case3	254 mm	250 mm

Element Formulation

The element formulation of the 2-D seatbelt elements was the third variable in the DOE. Element formulation 16 uses fully integrated shell elements and element formulation 9 uses membrane elements[5]. The fully integrated shell elements, due to its high bending stiffness, does not capture the seatbelt wrap-around the body blocks as accurately as membrane elements. Thus Case4, where membrane elements were used, displayed better seatbelt wrap-around the body blocks. This observation can be further substantiated by Figure 7, which shows that the internal energy of the membrane seatbelt elements is higher than the fully integrated seatbelt elements. This confirms that the membrane elements have better wrap-around capability as they absorb more energy.

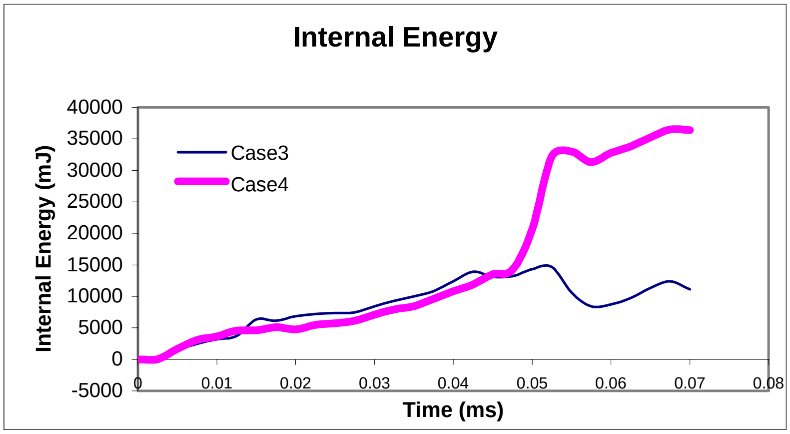

Figure7. Comparison of Seatbelt Internal Energy for Case3 and Case4

1-D Seatbelt Properties

The last variable studied in Case4 and Case5 was the 1-D seat belt that connects the 2-D elements to the seat anchor points and the pull chains. When regular seatbelt properties were used, the force was transferred to the seat, only after when sufficient tension was built into the seatbelt elements. This was not realistic representation of the actual test. Also the energy ratio, Total energy/Initial Energy, was very low with the regular seatbelt property. In LS-DYNA , seatbelt energies are not included in the total energy calculation. By stiffening the property of the seatbelt the energy ratio of 1.00 was achieved. Also, load was instantly transferred to the seat structure. Figure 9 compares the energy ratio , of the stiffer and the regular seatbelts.

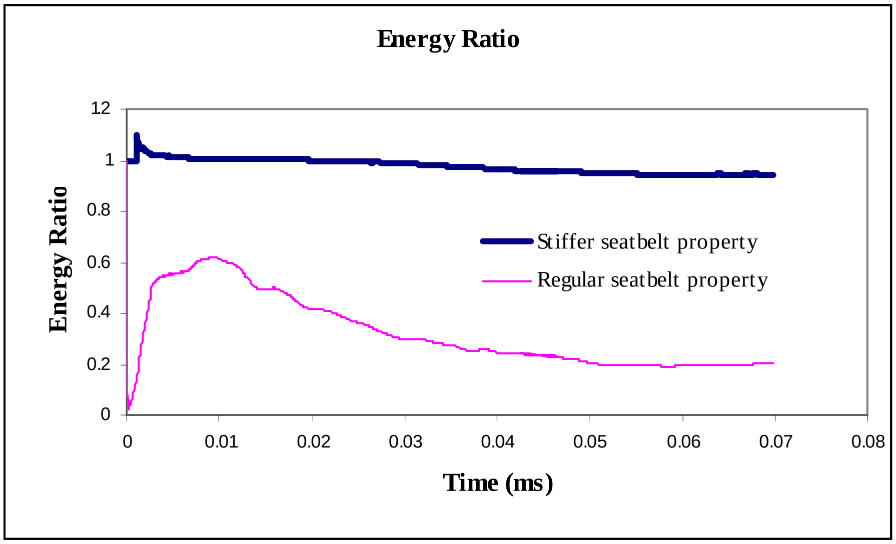

Figure 8. Comparison of Seatbelt Energy Ratio for Case4 and Case5

CONCLUSIONS

Using constrained, lighter body blocks, element formulation 9 for the2-D seatbelt elements and modified 1-D seatbelt property gave reliable results that correlated well with the physical test results, as shown in Figure 9. This methodology is used as a standard procedure in Lear's CAE group for FMVSS 207/210 simulation and has consistently correlated with the physical test for all the seating programs.

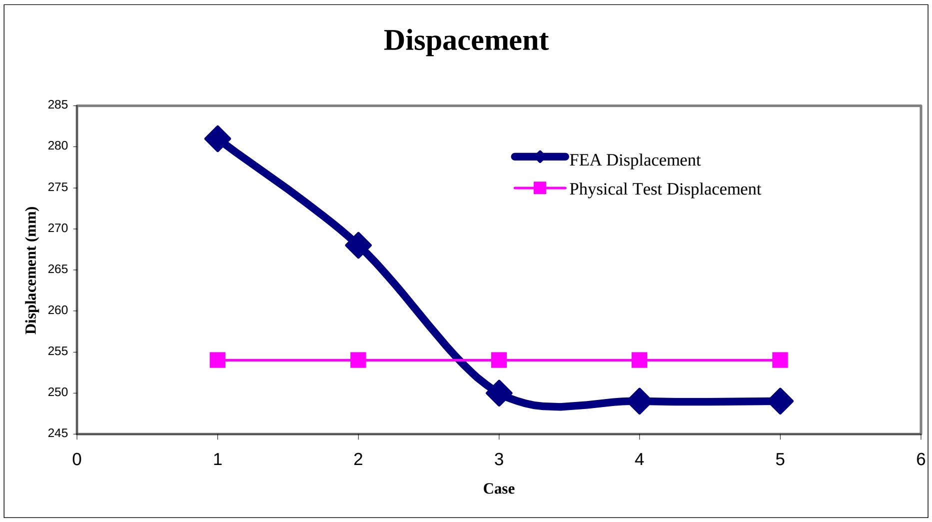

Figure 9. Comparison of Displacements for the DOE

ACKNOWLEDGEMENTS

The authors would like to thank Lear Corporation for encouraging the use of FEA as a part of the design and development process and allowing the group to experiment with new techniques. This work would have been incomplete without the input and suggestions from the test lab.

REFERENCES

[1] Federal Motor Vehicle Safety Standard (49 CFR PART 571): MVSS 207/210. Final amendment: FR Vol. 63 # 113 - 12.06.1998

[2] United Nations Agreement. Reg. Name: UN/ECE Seat Belt Anchorages. Reg. Number ECE-14.05, Page 15.

[3] HALDER, T. (2000), " Simulation of Structural Latches in an automotive seat system using LS-DYNA". 6th International LS-DYNA Users Conference, Dearborn, Michigan, USA.

[4] HALDER, T., MANNINO, V. F., and WILLIAMS, D. K. (1999). "Simulation of Bolts and Washers using LS-DYNA for Seat attachments and correlation with the test data". 2nd European LS-DYNA Users Conference, Gothenburg, Sweden.

[5] LS-DYNA User's Manual, V.950, 1999. LSTC, Livermore, CA.

[6] SCHWEIZERHOF, K., WALZ, M., RUST, W., FRANZ, U., KRICHNER, M. (1999). "Quasi-static Structural Analysis with LS-DYNA- Merits and Limits". 2nd European LS-DYNA Users Conference, Gothenburg, Sweden.

[7] XU, F., CHOWDHURY, P., SAMBAMOORTHY, B., HALDER, T. (2002), "Correlation of Federal Motor Vehicle Safety Standard 225 (FMVSS225) requirement of an automotive seat system using LS-DYNA". 7th International LS-DYNA Users Conference, Dearborn, Michigan, USA.