

Prediction of Seat Deformation in Rear Crash Using LS-DYNA

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Abstract

It has always been a challenging task to simulate occupied rear crash for seating system. To design an ideal seat for resisting the load during rear impact is also a difficult task for the seat suppliers. Seat Suppliers are in continuous search of newer methods and techniques to reduce number of prototypes and testing cost. Analytical methods of predicting structural behavior using computer aided engineering (CAE) has been in place for quite sometime. A CAE method using LS-DYNA has been developed at Lear Corporation to simulate the rear impact and to predict the seat deformation. Rear Crash simulation has been performed on a six-way power driver seats using this procedure and back frame deformation predicted by the simulation has been validated to the physical test and a good correlation has been achieved. This paper discussed the methodology adopted and the correlation achieved.

Abbreviations:

Federal Motor Vehicle Safety Standard (FMVSS)

Original Equipment Manufacturer (OEM)

Anthropomorphic Test Device (ATD)

Keywords: Rear Crash, Dynamic Analysis, Occupant Retention, Back Frame, Cushion Frame, Recliner, Suspension Lumber, FEA Simulation, Headrest, Dummy

Introduction

In any crash simulation the primary area of interest is occupant safety. In a rear crash of a seating system, occupant retention and injury of the occupant are the focus area. Occupant retention depends on the back frame deformation. If the deformation is high, occupant retention will be low and if the back frame deformation is more than 60 degrees¹ there is a possibility of occupant ejection. At the same time if the seat back is very stiff and deforms less, the occupant excursion will be high. Consequently, there is a high probability of occupant injury. The challenge is to design an optimum seat which will absorb energy as well as hold the occupant in the seat. Normally the back frame and the recliners absorb the major portion of the energy, and when these components sustain the load, part of the load will be passed to the cushion frame. Hence the primary focus will be on the deformation of back frame, recliner and the cushion frame in this simulation.

As a tier one seat supplier Lear Corporation supplies seat and other interior components to all major OEMs (Original Equipment Manufacturer) and the seats are designed to meet the specific OEM's standards. The acceleration and velocity pulse used for the simulation are supplied by the OEMs. The seat back deformation has to be within a specified angle. Normally a 95th percentile occupant is used unless specified otherwise. The occupant is positioned as per the torso angle and H-point of the seat. The basic simulation procedure is consistent for all seats except for the velocity pulse which depends on the vehicle.

Physical Test setup

Description of the Test setup: Figure 1 shows a physical test setup taken from the Lear Corporation Test Lab at Southfield, Michigan. Rear Impact test was done on a rigid fixture. A fully trimmed seat with headrest has been mounted on a rigid fixture. 95th percentile dummy has been positioned as per Federal Motor Vehicle Safety Standard (FMVSS) 208. The hands of the occupant were kept horizontal. The torso angle of the dummy was maintained same as the back frame angle of the seat. Both the legs of the occupant were tied loosely with a belt to avoid excessive movement of the occupant in case of the seat failure. The velocity pulse from figure 6 was applied to the rigid floor. The back frame deformation was measured from motion analysis.



Figure 1: Physical Test setup

Modeling Approach

Modeling of seat parts: Seat components were modeled as per Lear modeling standard. Minimum element size of 3 mm, warpage of 20 degrees, and aspect ratio of 5 were used for the quality of the elements. Weld locations were connected rigidly assuming no weld failures. Bolted joints were modeled with a beam and spider around the hole. Pins were modeled with beam elements with very low polar moment of inertia to allow the free rotation. Figure 2 shows a typical Seat FEA model.

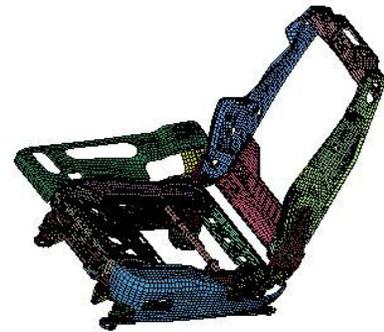


Figure2: Seat FEA model

Seat Position: Adjuster was in full down position and the track was in mid-travel position for this particular simulation.

Occupant (ATD): 95th percentile dummy was used as per the customer's requirement.

Positioning the occupant: The dummy was positioned as per FMVSS 208. The upper leg of the occupant was positioned as per the cushion foam shape on the seat. The torso angle of the dummy was the same as back frame angle. The feet of the dummy were put at the heel point coordinate. The lower arms and hands of the dummy were made horizontal. Figure 3 shows a 95th percentile occupant.

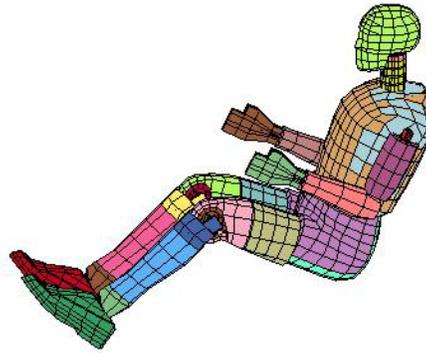


Figure 3: 95th percentile Hybrid III Rigid dummy

Modeling of Cushion Foam and the Back Foam: The cross section of the cushion foam was adjusted to accommodate the occupant at the desired H-point. The cross section of back foam was also adjusted to position the occupant at the desired torso angle. Null shell elements were used to avoid negative volume in both the cushion and back foam. Figure 4 shows a mesh of the adjusted cushion and back foam. Foam was modeled using material model MAT57. The stress-strain curve for the foam obtained from the Lear Corporation test laboratory was slightly modified to have better

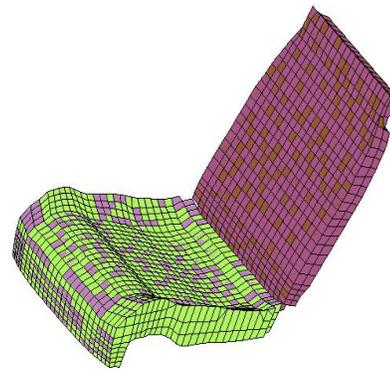


Figure 4: Cushion & Back foam

Modeling of Suspension and Lumbar: The suspension of the seat was modeled using spring and beam elements coincident to the nodes of the foam surface. Spring elements were connected to the cushion frame and back frame in an appropriate location. If the seat contains a lumbar instead of a suspension, steel parts of the lumbar need to be modeled to support the back foam. The steel parts should also be connected to the back frame.

Modeling of Headrest: Since the headrest plays a very important role in rear crash, the headrest rod and other headrest mechanisms were also modeled. The headrest foam was attached to the headrest rod by using a rigid connection. The headrest was locked at the full up position.

Contacts between the Dummy and Seat: An automatic single surface contact was defined between all seat components. Automatic single surface contact was also defined between dummy and foam components. A Static Coefficient of friction of 0.3 and a sliding coefficient of friction of 0.2 were used. An automatic single surface contact was also defined between the head of the dummy and headrest foam. Figure 5 shows a FEA seat



Figure 5: FEA Model

Loading and Boundary conditions: A velocity pulse was applied to the rigid floor in the simulation. The floor was constrained in all directions except in the global X-Direction. The seat floor mounting brackets were bolted to the rigid floor. The analysis was run for 200 millisecond to observe the rebound of the occupant.

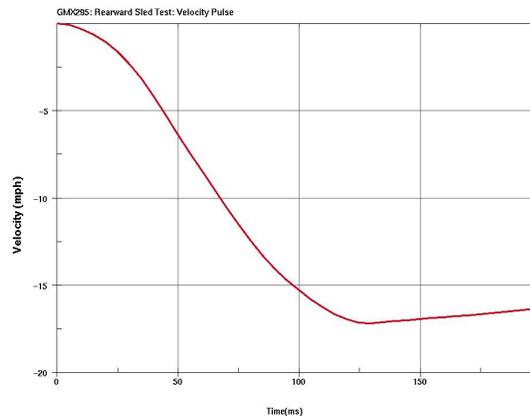


Figure 6: Velocity Pulse

Results and Discussion

Results from FEA simulations were validated by a physical test. Back frame deformations measured from vertical were compared. Figure 7 shows the comparison between the back frame deformation observed in the physical test and in the FEA simulation. As seen from the curves the correlation between the test results and the FEA simulation was good. There was some difference between the two curves in the beginning and at the end portion of the simulation. The difference at the start was due to foam absorbing more energy initially in the FEA simulation

than in the actual test. The interaction of the foam and the occupant is still a grey area and this will be the future scope of work for extending the study. The difference between the two curves at the end of the simulation tells us that the FEA simulation predicts more plastic deformation in the seat than in the physical test. This can be attributed to the effect of stamping. Most of seat components were manufactured by stamping operations. Material properties vary from one stamping operations to another. These variations of the material properties were not considered in the simulation.

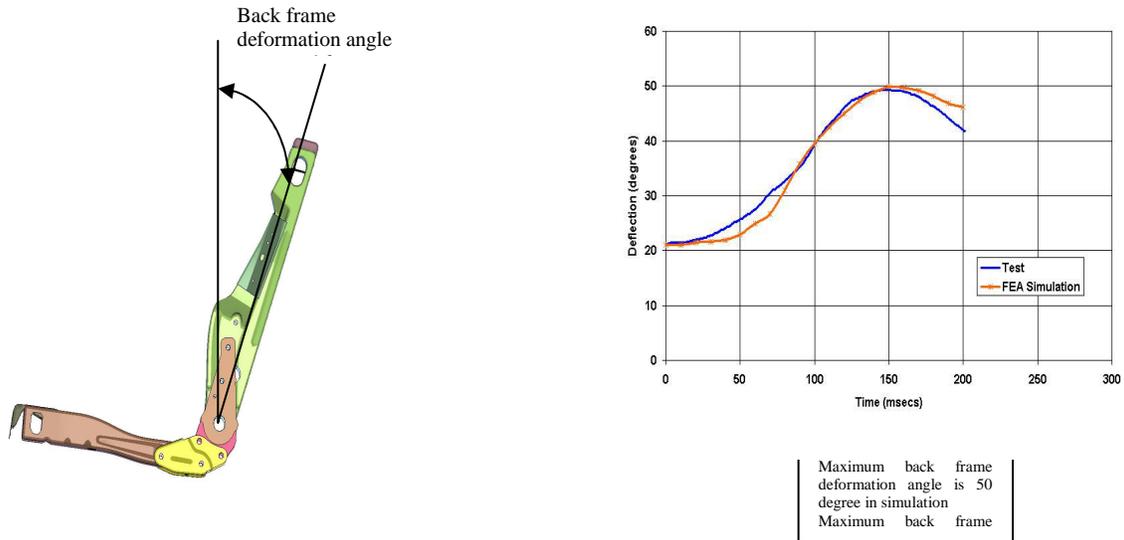


Figure 7: Back frame deformation comparison between the physical test and the FEA

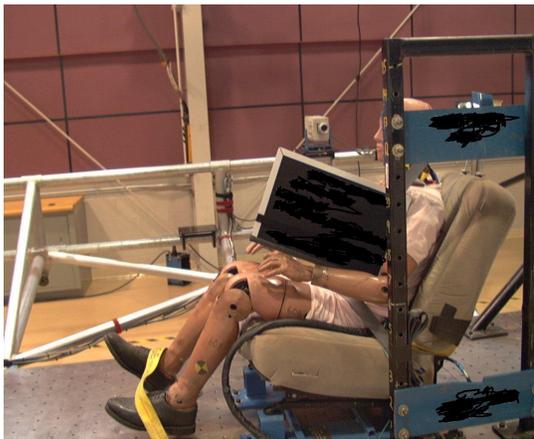


Figure 8a: Picture of the occupant and the deformed seat at 200 millisecond in Physical Test

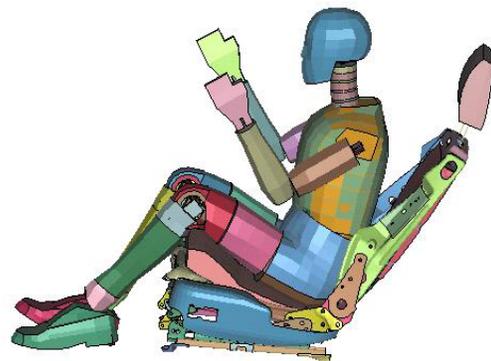


Figure 8b: Deformed shape at 200 millisecond in FEA simulation.

Figures 8a and 8b show the deformed condition of the seat and the occupant in the physical test and in FEA simulation respectively. The deformation of the seat structure in the FEA simulation was similar to the deformation of the seat structure observed in the physical test.

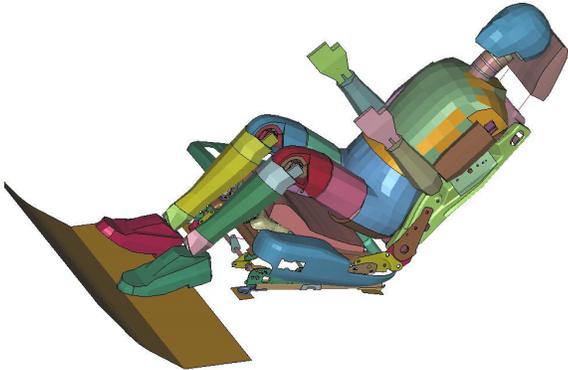


Figure 9a: Deformed shape of the seat structure and the occupant at 150 millisecond in simulation

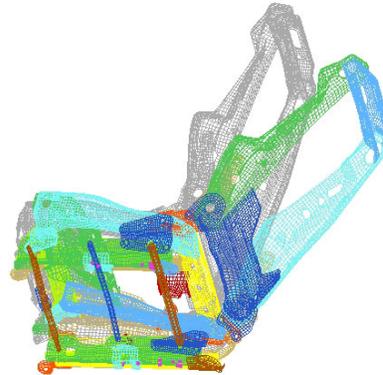


Figure 9b: Deformed and original shape of the seat structure at 150 millisecond in simulation

Figure 9a shows the deformed seat structure and the occupant at maximum deformed condition. The occupant started rebounding after 150 millisecond. Figure 9b shows the deformed seat structure at 150 millisecond and the original shape of the seat structure.

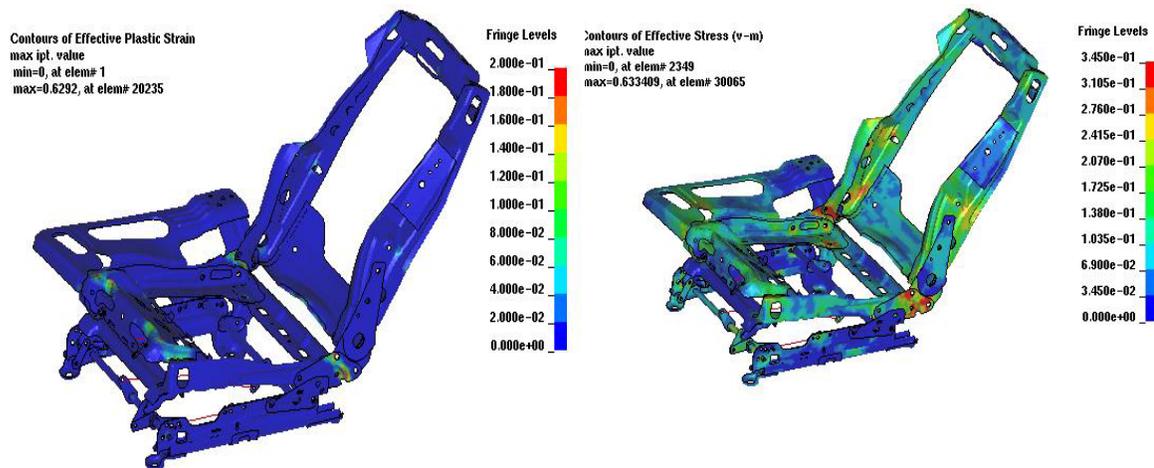


Figure 10a: Effective plastic Strain on the Seat structure at 150 millisecond

Figure 10b: Von Mises Stress Plot on the Seat structure at 150 millisecond

Figure 10a and 10b show the effective plastic strain and Von Mises stress plot on the seat structure at 150 millisecond.

Assumptions

1. The recliner's internal mechanism (Gear tooth) was not modeled in the FEA simulation. No tooth failure was assumed.
2. The strain hardening effect of the materials was not included.
3. Welds were modeled as rigid connections assuming no weld failures.

Conclusions

It is clear from Figure 7 that maximum back frame deformation from simulation (50 degrees) is very close to the test value (48 degrees). So the results from FEA simulations correlated well with the physical test and using this modeling approach occupied rear crash can be simulated accurately.

Future Scope of work

Foam properties and the interaction between the foam and the occupant are possible areas of future study. Occupant's kinematics depends a lot on the foam behavior. Occupant injury study and neck response analysis will also be included in the future work.

Acknowledgement

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References

1. VIANO, DAVID C. , Role of the Seat in Rear Crash Safety, SAE Publication
2. CAE Methodology for Vehicle Crash Safety, SAE International SP-1774
3. 7th International LS-DYNA Users Conference 2002 Proceedings.
4. HALLQUIST, J.O., LS-DYNA, Theoretical Manual
5. LS-DYNA Keyword Users Manual, Version 960.
6. Federal Motors Vehicle Safety Standard (FMVSS 208), published by National Highway Safety & Traffic Administration (NHSTA)
7. 41st STAPP Car Crash Conference Proceedings
8. ISATA, 2000 proceedings.
9. DUBOIS, P. and HALLQUIST. J. O., Advanced Crash & Safety Training Class material