

Finite Element Analysis of Captain Seat as per FMVSS 225

Sumit.R.Patil^{1}, A. M. Naniwadekar²*

ABSTRACT

Considering safety in automobile child restraint systems are considered as highly effective devices. These devices protect child from causing or undergoing serious injuries and fatal accidents during an event of crash. Different types like rear facing harness, forward facing, seat belts, and booster seat with lap and shoulder belt restraint systems are present. The main purpose to be served by these restraint systems is protection to occupant. Booster seats with proper belt positioning provide minimum injury as per research data. In previous studies, it is found that booster seats are effective. The Objective of present work is to perform FEA analysis on captain seat as per FMVSS 225 and to find overall stresses and strains plot.

Keywords: Child Safety, Seat belts, Top Tether, LATCH, Head and neck injury.

1. Introduction

In olden days, automobile bodies were made up of hard and less stiff material. As time passed there were new advancements in technical fields and growth of infrastructure is done. With this progress speed limit of vehicles has seen drastic rise. Due to this increase in speed, accident rate and serious deaths and injuries also increased drastically. In order to avoid fatalities and injuries due to this condition safety precaution has been the most important thing in automobiles. As new vehicles are launched with keeping competition in mind customers are also demanding improved safety along with power and performance of vehicle. Coming through last decade improved and new safety features and devices like restraints system, airbags. These devices help to sustain crash at a speed of 50 kmph. Without use of such restraints devices at such a speed a passenger who isn't restrained at all would be just thrown away with a force more than that of body weight. In that scenario imagine passenger is a infant then the case would be much worse.

Category of seats as per child age:

Four main sequential categories in child restraint system:

- Rear facing harnessed restraint
- Forward facing harnessed restraint
- Booster seat with a lap and shoulder belt restraint
- Seat belts.

Child safety restraint system is the seats designed to protect children from fatal injury during motor vehicle crashes. Commonly these seats are purchased separately and installed in vehicle as and when required. There are different types of seats as per the age, weight and height. These seats are attached to vehicle seat by LATCH and seat belt. When motor vehicle crash takes place, due to sudden deceleration of the vehicle large amount of force is generated. The force generation time is too small. The generated force is absorbed by different parts of vehicle. Such a short duration and high amplitude force is transmitted to occupant which may cause fatal injury to occupant. If the occupant is restrained in the specific seat which is suitable for their weight, height and size then the chances of injury potential reduces drastically. Purpose of child restraint systems is to reduce injury in crashes.

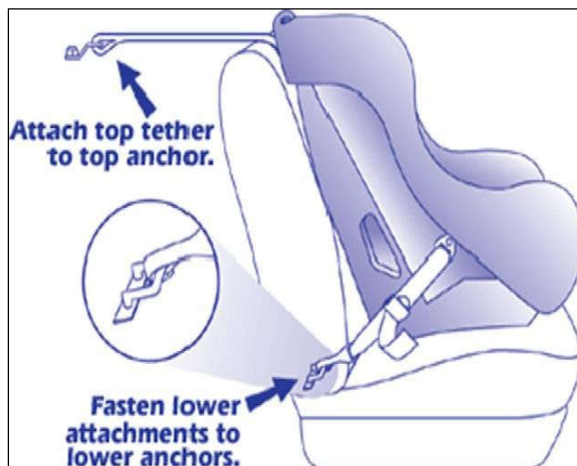


Figure 1 Forward facing child restraint system. [2]

Problem Statement and Objective:

Current design of seat structure isn't evaluated for its strength in crash performance. To meet safety standard requirement seat structure is analysed using various parameters such as size, shape, thickness, material properties etc.

Objective of this study is to analysis the current commercial car seat structure. Due to the accident cases, it seems that the current child car seat design is not sufficient enough to withstand the collision impact. The study aims at understanding and identifying the seat strength for a chosen seat configuration. The study also analysed child car seat using FMVSS 225 and proposed new design. The others objective focused on using different material systems in lightweight designs. Traditionally, using thinner sheets of steel reduced component weight. This technology cannot be further developed so the need for new materials and design becomes more important. Literature survey regarding Child Restraint System, FE crash and safety analysis.

- Learning FE tools like Hypermesh and LS Dyna to validate seat structure.
- FE modeling of Captain Seat using Hypermesh.
- Testing of seat structure for regulatory requirements using LS Dyna.
- Modify seat design to meet regulatory requirements.
- Conclusion and future scope.

2. Study of Safety Regulations

2.1 Existing laws and regulations in different countries for safety:

In developed countries there are different regulations for vehicle safety. Like FMVSS200A for whiplash safety in rear impact collision, FMVSS216 for roof crush analysis, FMVSS208 for frontal crash, FMVSS301 for rear impact, FMVSS210 for anchorage testing of driver seat etc.

Following are some of the regulations related to child safety in different countries.

- FMVSS225 (Federal Motor Vehicle Safety Standard)
- ECER14 (Economic Commission for Europe)
- ADR34 (Australian Design Regulation)
- CMVSS 208 (Canadian Motor Vehicle Safety Standard)

2.2 FMVSS225

Appendix A. Federal Motor Vehicle Safety Standard (FMVSS) 225 standard establishes requirements for child restraint anchorage systems to ensure their proper location and strength for the effective securing of child restraints, to reduce the like this of the anchorage systems failure, and to increase the like this that child restraints are properly secured and thus more fully achieve their potential effectiveness in motor vehicles. This standard applies to passenger cars, multi purposed passenger vehicles, and goods vehicle with gross vehicle weight rating of 3,855 kg or less and to buses (including school buses and multi-function school activity buses) with GVWR of 4,536 kg or less. This type of standard cannot be applied van category, public transport buses.

There are four tests for FMVSS 225 –

- Forward pull with top tether
- Forward pull without top tether
- Lateral pull to the right
- Lateral pull to the left

2.3 Top Tether Anchorage Strength Requirements

The tests are performed by applying a specified load to the child seat anchorage system using Static Force Application Device (SFAD), mandated by NHTSA. The regulation requires there should not be any structural separation of the load application point on the SFAD.

Table 1 Top Tether Anchorage Strength Requirement

	Preload (N)	Force application angle measured at preload (degrees)	Time to Reach Required Force (s)	Required Force (N)	Required Hold Time (s)
SFAD1	500	5 to 15	24 to 30	15000	1
SFAD2	500	5 to 15	24 to 30	15000	1

3. Baseline Design Modeling

The baseline seat model is given for assessment as a pilot project by one of the clients of my company where I work, who are sponsors of this project. Seat modelling is decided according to requirement stated by the client in their proposal. This is second row two way captain seat. Second row seat is taken because regulation suggests that child seat is installed on second or third row seat.

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A. Seat Structure

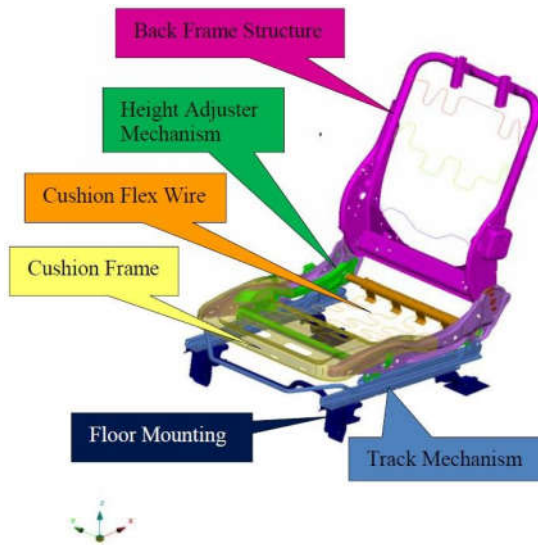


Figure 2 Seat Frame Structure

In the following figure seat structure details are mentioned. Few important components like back frame structure, height adjuster mechanism track mechanism, back frame structure, cushion flex wire, cushion frame, track mechanism, floor mounting are shown.

4. Fea Model Setup

As per FMVSS 225 the seat test setup for pull test and check for structural integrity. The test specifications and test requirements are given below:

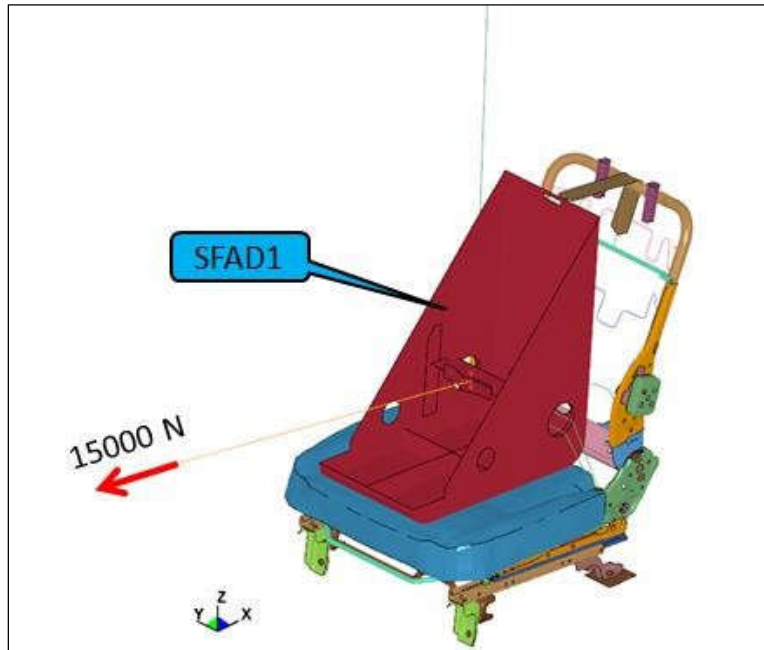


Figure 3 Seat Position: Full Rear and Full Down

The test set-up consists of SFAD1 device positioned on seat which is in Full Rear Full Down position. A load of 15000 N (100%) is applied at 10° to horizontal and hold, then the load is ramped up to 18000 N (120%) overload to check the seat performance.

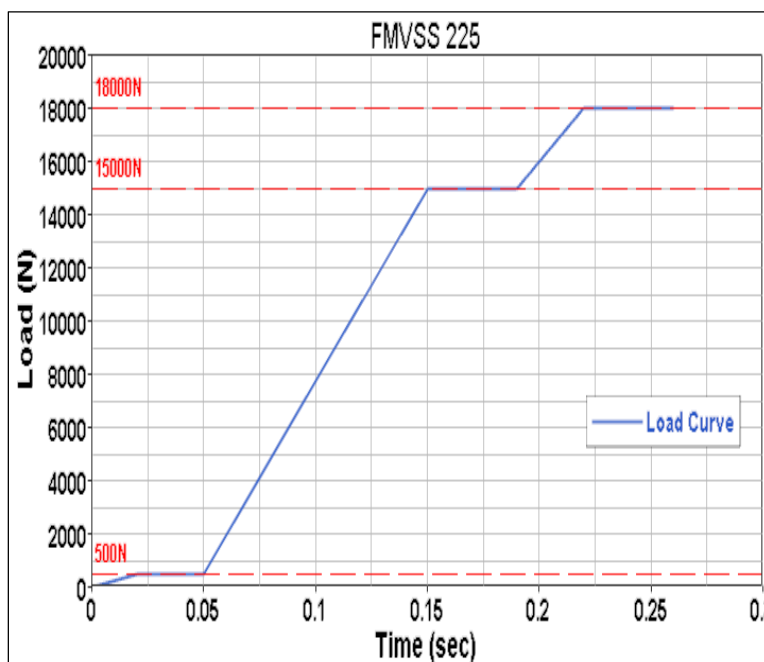


Figure 4 Load Curve

In figure X axis shows the time in sec and Y axis shows the load Newton's. A load of 500 N is applied at 0.00 to 0.02 second and hold at up to 0.05 second. Then a load of 15000 N (100%) is applied at 10° to horizontal at 0.05 to 0.15 second and hold at up to 0.19 second, then the load is ramped up to 18000 N (120%) overload at 0.19 to 0.22 second and hold at up to 0.26 second to check the seat performance.

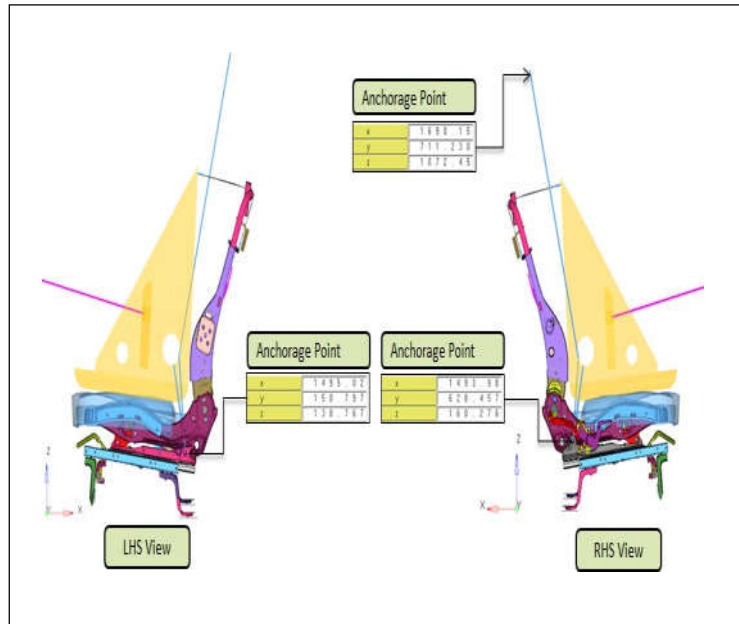


Figure 5 Important Seat Co-ordinates

In above figure shows the important seat co-ordinates of anchorage points. In seat lower side two and upper side one anchorage point which is fixed on seat structure and frame of car.

5. Results And Discussion

Baseline seat model is submitted for simulation in LS-DYNA. The results of simulation are shown in figure 6 to 8 which clearly indicates that seat failing for requirements as per FMVSS 225. Seat does not meet structural integrity criteria as floor mounting, cushion member and track mechanism for installing child safety restraint system on it. It is required to make suitable design changes and material changes in order to avoid the failure. A strength enhancement is needed in critical components such as floor mounting, cushion member and track mechanism.

Animations Instances

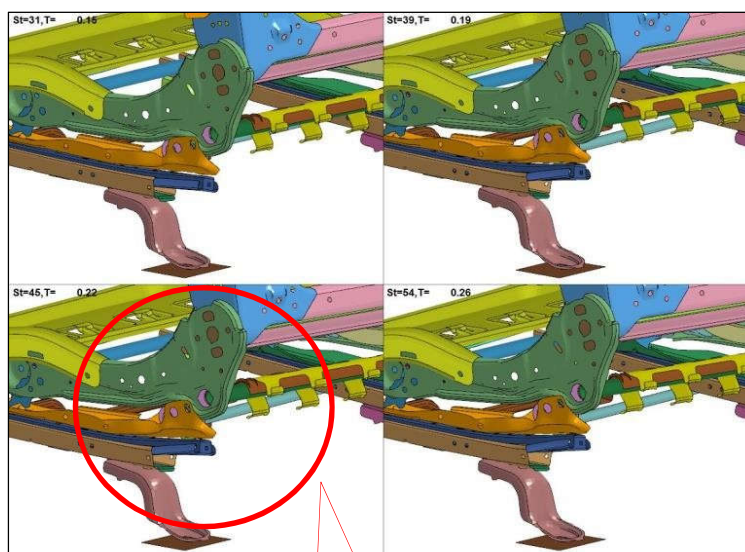


Figure 6 Failure Region
Failure region

In figure shows the animation instant at time of 0.015sec, 0.19sec, 0.22sec and 0.026sec. Failure region shows the structural performance during load applied.

Overall stress plot

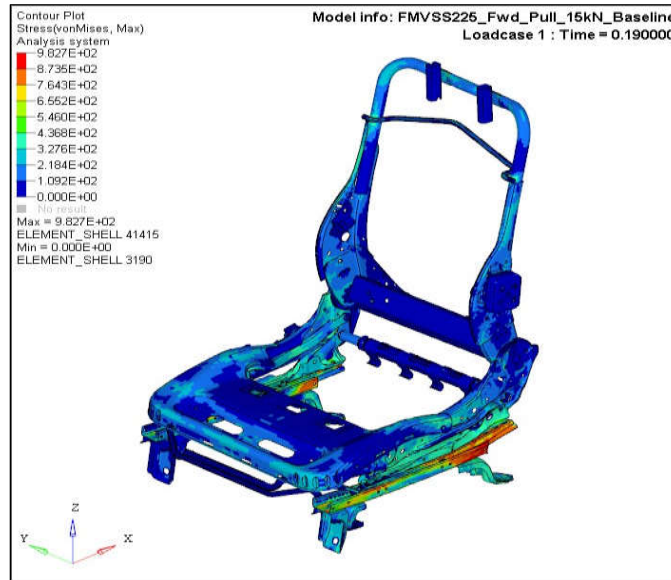


Figure 7 Overall Stress Plot

In above figure shows the overall stress on seat frame at applied load at 15000N. The high stress is generated in floor mounting, cushion member and track mechanism.

Overall Plastic Strain Plots

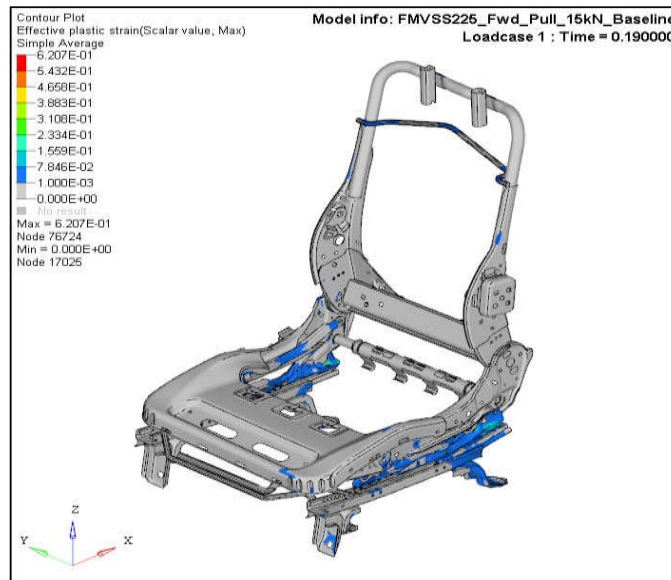


Figure 8 Overall Plastic Strain

In above figure shows the overall strain on seat frame at applied load at 15000N. The high strain is generated in floor mounting, cushion member and track mechanism.

REFERENCES

- [1] T. Kapoor, W. Altenhof, Anne Snowdon, Andrew Howard, Jim Rasico, Fuchun Zhu, Daniel Baggio, A numerical investigation into the effect of CRS misuse on the injury potential of children in frontal and side impact crashes, *Accident Analysis and Prevention* 43 (2011) 1438–1450.
- [2] Kristy B. Arbogast, Jessica Steps Jermakian, Field use patterns and performance of child restraints secured by lower anchors and tethers for children (LATCH), *Accident Analysis and Prevention* 39 (2007) 530–535.
- [3] Matthew P. Reed, Sheila M. Ebert-Hamilton, Kathleen D. Klinich, Miriam A. Manary, Jonathan D. Rupp, Effects of vehicle seat and belt geometry on belt fit for children with and without belt positioning booster seats, *Accident Analysis and Prevention* 50 (2013) 512– 522.
- [4] Tanya Kapoor, William Altenhof, Qian Wang, Andrew Howard, Injury potential of a three-year-old Hybrid III dummy in forward and rearward facing positions under CMVSS 208 testing conditions, *Accident Analysis and Prevention* 38 (2006) 786–800.
- [5] Karin Brolin, Isabelle Stockman, Marianne Andersson, Katarina Bohman, Laure-Lise Gras, LottaJakobsson, Safety of children in cars: A review of biomechanical aspects and human body models, *IATSS Research* 38 (2015) 92–102.
- [6] Christina M. Rudin-Brown, Jason K. Kumagai, Harry A. Angel, Kim M. Iwasa-Madge, Y. Ian Noy, Usability issues concerning child restraint system harness design, *Accident Analysis and Prevention* 35 (2003) 341–348.
- [7] Charles E. Cunningham, Beth S. Bruce, Anne W. Snowdon, Yvonne Chen, Carol Kolga, Caroline Piotrowski, Lynne Warda, Heather Correale, Erica Clark, Melanie Barwick, Modeling improvements in booster seat use: A discrete choice conjoint experiment, *Accident Analysis and Prevention* 43 (2011) 1999– 2009.
- [8] Kathleen D. Klinich, Miriam A. Manary, Carol A.C. Flannagan, Sheila M. Ebert, Laura A. Malik, Paul A. Green, Matthew P. Reed, Effects of child restraint system features on installation errors, *IATSS Research* 38 (2015) 92–102.
- [9] S. Nakahara, M. Ichikawa, S. Wakai, Magazine information on safety belt use for pregnant women and young children, *Accident Analysis and Prevention* 39 (2007) 356–363.
- [10] Mulla Salim H, Yadv Sanjay D, Dhananjay Shinde, Gaurav Deshpande, Importance of Federal Motor Vehicle Safety Standards 207/210 in Occupant Safety - A Case Study, 64 (2013) 1099 – 1108.
- [11] Dinesh Mohan, *Accidental Deaths & Suicides in India - 2007*. New Delhi, National Crime Records Bureau, Ministry of Home Affairs. (2008).
- [12] Ministry of Road Transport & Highways Government of India, *Report of Road Accidents in India Issues & Dimensions – 2012*