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Subsystem Level Frontal Crash Validation of Automotive Seat

Ashish Balaji Kotapalle[1] **and Mr. P. G. Sarasambi**[2]
P.G. Student, Department of Mechanical Engineering[1]
Assistant Professor, Department of Mechanical Engineering[2]
Shree Ramchandra College of Engineering, Pune, India

Abstract: *The scope of this research encompasses a comprehensive investigation into the crashworthiness of automotive front seating systems under frontal impact conditions, with specific emphasis on subsystem-level validation. The primary objective is to identify optimal structural design modifications within the seat architecture to enhance occupant safety, while adhering to organizational constraints that preclude material substitution. The study employs Finite Element Analysis (FEA) using LS-DYNA (v971R4) to simulate offset frontal crash scenarios at 67 km/h, which impose more severe loading conditions compared to the ECE R94 protocol.The methodology integrates sled-based crash simulations with dummy kinematics evaluation, anti-submarining performance assessment, and biomechanical criteria quantification (H-point displacement, pelvis rotation, and acceleration). Critical parameters such as seat belt load limiter calibration, cushion cross-member deformation, and plastic strain distribution are analyzed to establish correlation between numerical predictions and physical test outcomes. High-speed video tracking and accelerometer data provide experimental benchmarks for validating FEA results.The study demonstrates that FEA outputs exhibit strong agreement with experimental sled tests, confirming the reliability of LS-DYNA in replicating real-world crash dynamics. To mitigate excessive dummy displacements and ensure compliance with regulatory thresholds, innovative tube-in-tube reinforcement strategies and riser redesigns were implemented within the seat structure. These design interventions significantly improved energy absorption capacity, reduced structural deformation, and maintained biomechanical responses within prescribed safety limits.*

Keywords: LS-DYNA, Finite Element Analysis, Frontal crash, ECE regulations etc

I. INTRODUCTION

Frontal impact test is based on that developed by European Enhanced Vehicle-safety Committee as basis for legislation, but impact speed has been increased by 8kph. Frontal impact takes place at 64kph (40mph), car strikes deformable barrier that is offset. Front crash for subsystem level is taking place from the full vehicle front crash protocol. For this study speed is used 67kph as per norms which are sever than the offset frontal crash protocol under ECE 94 [22].

II. METHODOLOGY

2.1 Purpose

This procedure describes the methodology to realize a front impact on sled facility procedure is applicable on front and rear seat for tests realized on jig without frontal airbag restraint. It should be applied in FEA endorsing/supporting tests or R&D tests:

- Seat structure evaluation
- Seat and dummy kinematics
- Anti-submarine evaluation

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- Biomechanical criteria measurements

2.2 Required elements

Product to be tested should be controlled and representative from definition. A H- point measurement, according to SAE J826 should have been done before test. These results are the H-point reference for dummy positioning. The product should be fully equipped with serial restraint system (buckle, active anti-submarine system except specific customer's request).

Seat belt: is representative from the serial customer belt used in vehicle or from customer's specific requirements for jig tests (I.E. belt load limiter @600dan instead of 450daN taking into account front airbag restraint if requested by customer). Firing equipments with Time to Fire (TTF) are defined by project. The firing system on sled should be synchronized with the T0 value (defined in following paragraph).

Jig representative from vehicle for belts anchorages, seat anchorages (including contact surfaces between jig and seat), and floor environment, heel position and feet inclination. Note that the upper belt anchorage should be adjustable to the 3 dummies type positions (5th, 50th and 95th).

Jig for rear seat: By default, for rear seat, the previous row should be simulated according to customer specification, to avoid abnormal displacement of the occupants. (Examples: 40mm diam. Tube for French customers, Stiff plate with foam back for Skoda, dummy seats for GM.)

Acceleration pulse: Defined by customer. Calibrated on sled. X acceleration measured on sled with 2 accelerometers positioned on left and right side.

Videos and Tracking: High speed cameras @1000fps. 2 lateral views (onboard or outboard). A specific view should film complete pelvis kinematics.

2.3 Validation Study:

The FEA front seat model build is used to simulate frontal crash into a offset barrier at 67 Km/hour, using LS-DYNA (version: 971R4).Overall global pattern for FEA results are matching with actual test. The comparison between actual test and FEA is discussed in following points.

Input acceleration pulse comparison

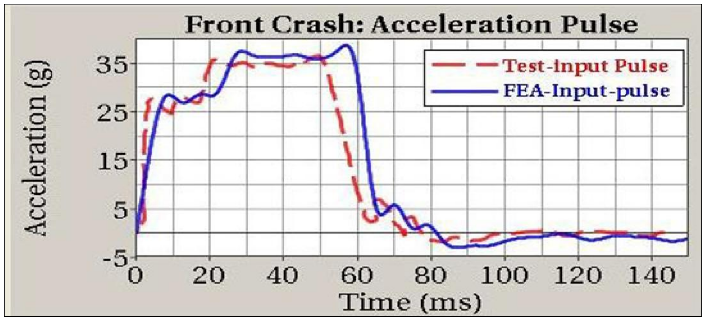

Figure 1 : Input acceleration pulse comparison

Seat deformation comparison

Cushion cross member behaviour is same in FEA as compared with actual test shown in fig below.

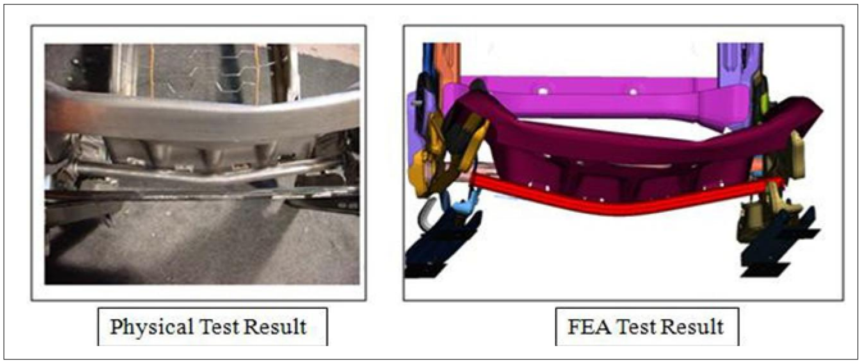

Figure 2 : Seat deformation comparisons

Twisting of cushion pan is same in FEA as compared with actual test shown in figure below.

Figure 3 : Twisting of cushion pan

Plastic Strain Comparison

Overall plastic strain for complete seat

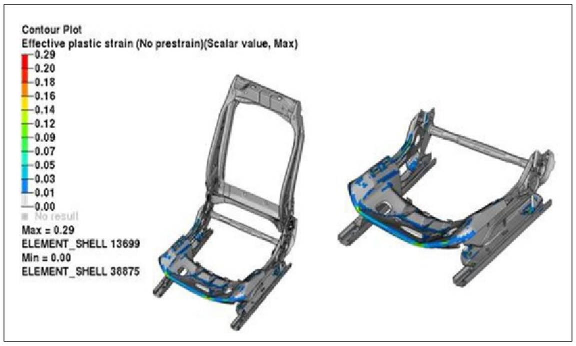

Figure 4 : Overall plastic strain of front seat

Graphical presentation of dummy biomechanical criteria

To get the dummy biomechanical outputs accelerometers are fitted at different locations of dummy.

Dummy H point displacement

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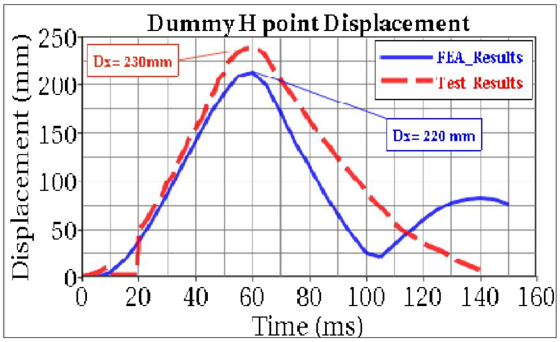

Figure 5 : Dummy H point displacement comparison

III. RESULTS AND DISCUSSION

As seen in figure 5 above H point displacement in X direction of dummy is 220mm and physical test the value is 230mm so FEA results are almost matching with physical test results. Targeted value of dummy X displacement as per ECE regulatory requirement is 185mm.To minimise the dummy D displacement within regulatory requirement we have come up with the solution as below.

Use of two concentric tubes of thickness1.2mm and thickness1.5mm were done. Change in riser design. All the new design changes are explained in figure 6 below

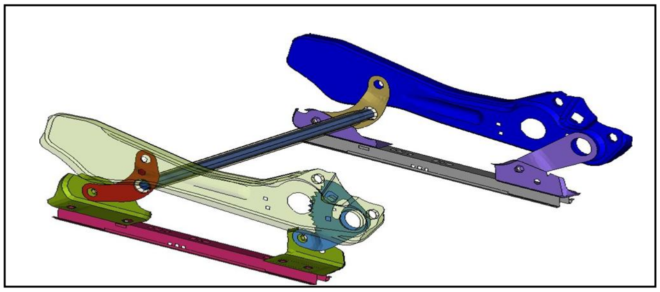

Figure 6 : Tube in tube technique for cushion front cross member

FEA results shows cushion front cross member displacement is 24mm.

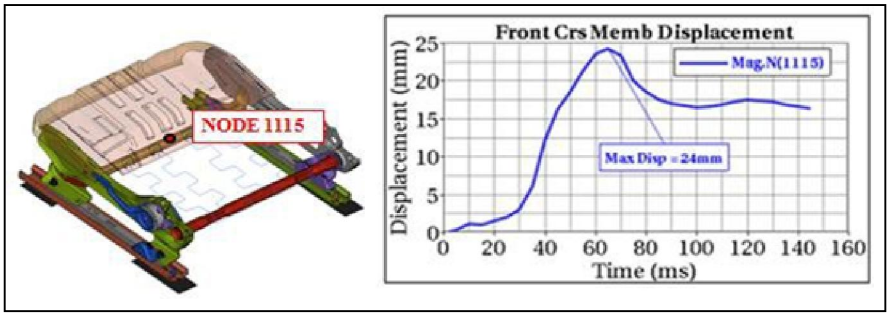

Figure 7 : Cushion Front cross member displacement

Dummy biomechanical criteria

Figure 7 below shows the information regarding dummy X and Z displacement and other biomechanical criteria's for dummy.

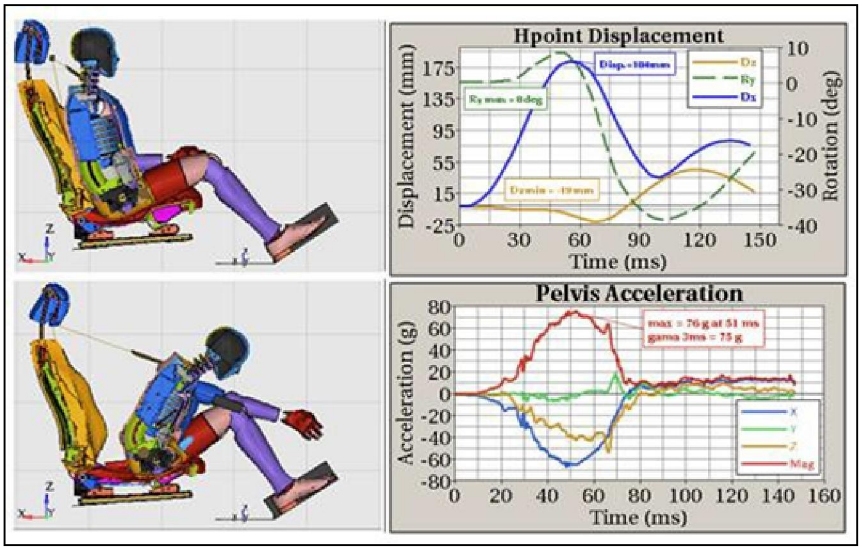

Figure 8 : H point displacement and Pelvis acceleration

As shown in figure 8 above shows that:
Dummy X displacement= 184mm <185mm (Regulatory Criteria)
Dummy Z displacement = -19mm (negative Z direction) < -30mm
Rotation of dummy pelvis = 8 degree <15 degree
Pelvis acceleration = 76g.<80g

IV. CONCLUSION

The study confirms that LS-DYNA FEA simulations are a reliable tool for predicting seat crashworthiness under severe frontal impact conditions, providing results consistent with physical tests. The proposed structural reinforcements (tube-in-tube design) successfully minimized dummy displacements and ensured compliance with ECE safety criteria, making the methodology suitable for both R&D validation and regulatory support.

V. FUTURE SCOPE

As a continuation to this work one can try to find the new alternative solution by using following options:
Using different light weight materials for seat components for weight optimization.
New techniques of combination of plastic and steel over molding techniques to increase stiffness of the components and also reduce the weight of the seat.
Check the seat for other ECE seating regulations such as ECE 17-energy dissipation test, Luggage impact test.
Also check the seat for FMVSS (Federal Motor Vehicle Safety Standards-American regulations).

REFERENCES

[1]. Chong Liu, Kun Li, Yutao Liu, Xiaojiang Lv, Yonghui Wang, Dayong Zhou, Heping Yang, “A Preliminary Study of Occupant Kinematics and Injuries in a Frontal Crash with Occupant Face-to-Face Scenario,” 2025, SAE Technical Paper 2025-01-8736, SAE International, WCX SAE World Congress, pp. 1–12.

[2]. “LS Dyna 971 Theory Manual”, Release July 2010, Livermool Software Technology Corporation, California ,pp 1-2500.

[3]. Erik Brynskog, Jonas Östh, Karl-Johan Larsson, Johan Iraeus, “Effect of Occupant and Restraint Variability in Reclined Positions on Submarining Probability in Frontal Car Crash Scenarios,” 2025, *Frontiers in Bioengineering and Biotechnology*, Vol. 13, Article 1523456, pp. 1–18.

[4]. IJERT Authors, “Simulation of Car Frontal Fascia During Crash Using LS-DYNA,” 2019, *International Journal of Engineering Research & Technology (IJERT)*, Vol. 8, Issue 6, pp. 123–130.

[5]. Driss Bendjaballah, Mohamed Sahli, Thierry Barrière, “Modeling and Numerical Simulation of Car Frontal Crash Test Using Finite Element Method,” 2025, *Journal of Materials Science: Materials in Engineering*, Springer, DOI: 10.1186/s40712-025-00326-4, pp. 1–15