Safety Enhancement in Vehicle Design to Prevent Neck Injury Due to Rear Impact using Finite Element Analysis

Prakhar Amrute[1], Mayank Chandwani[2], Anil Lashkari[3]

[1]Department of Mechanical Engineering, MediCaps Institute of Technology and Management, Indore
[2]Department of Mechanical Engineering, MediCaps Institute of Technology and Management, Indore
[3]Indore Institute of Computer Aided Engineering, Indore

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Abstract - *Every year many peoples survive due to neck injuries in rear-impact crash of the vehicle. It seems to be low speed crash but injuries are very severe. Experimentally it is very costly and sometimes impossible to find the cause of these fatalities. Finite Element Analysis is an imperative simulation tool in mechanical engineering to analyze these events precisely. In this study, finite element method was used for whiplash injury prediction that takes in to account injury criteria using crash dummy model. The crash dummy model will integrate with seat model and perform test as per rear-impact crash scenario, further modifications will be done in seat structure design to improve the safety during rear impact.*

*Key Words***:** Whiplash Injury, Finite Element Analysis, Rear impact cash, Dummy model.

1. INTRODUCTION

According to WHO's infographics on road safety data, nearly 1.25 million people die in road crash every year, on average 3287 death a day and approximate 20 million peoples are injured and disabled. This data includes different type of crash like frontal, rollover, side, rear and unknowns. The rear impact crash is 28%, and risk of whiplash injury factor in rear crash is 80 % as compared to other crash. Further, unlike the risk of AIS3+ injuries, the risk of whiplash injury is approximate the same at high and low speeds. A whiplash neck strain is occurs when your head is suddenly jolted backward and then forward, like the cracking of whip. This motion can injure the bones in the spine, disk between the bones, ligaments, muscles, nerves and other tissues of the neck. In our study, we design Seating system for occupant comfort and protection against whiplash injury.

2. METHODOLOGY

In that case we design seat model as per required dimensions than integrate with crash dummy model and perform rear impact test processor defined by Euro NCAP and modification done in seat structure as per manufacturer speculations.

2.1 CAD MODEL

There three cad model developed using Cre-o parametric 3.0, without headrest (Seat 1) , with head rest poor rated (Seat 2) and with headrest fair rated (Seat 3).

Fig -1: Three Dimension model of vehicle seat.

2.2 PRE-PROCESSING

Hypermesh 13.0 used as a pre-processor, the different type of element are used in model according to subparts, like 3D tetrahedral elements are used in seat back, seat base, headrest and headrest mills, and 2D tria elements are used in fabric material. The average size of element is 30, model consist of 24,364 elements and 4990 nodes.
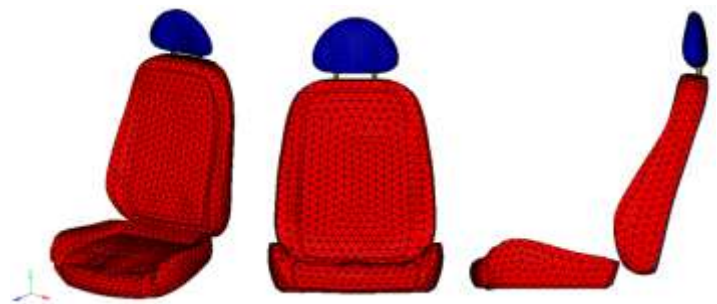

Fig -2: FE Model of seat

2.3 MATERIAL PROPERTY

Material assigned according to subparts as show in table below.

Table -1: Material Cards in Ls-Dyna.

Material Type	Component
MATL57	Foam of the seat back
MATL20	Headrest mills
MATL9	Model of the Fabric

2.4 DUMMY MODEL

The 50th percentile hybrid III dummy model was used in the safety assessment because hybrid III dummies are most usable crash test dummy in the world for the evolution of automotive safety restraint systems in frontal crash testing .This model is consisting of mix major assemblies head, neck, torso, pelvis, arm and leg. The all assemblies are connected are as follow, the head is connected to neck through by revolute joint at optical condyle. The neck is connected to torso through rigid constraints. Arms are attached with torso through revolute joint at solder position. The pelvis is connected to torso through rigid constraints applied at the base of lumber spine mount and legs are attached to the pelvis through spherical joint.

**Table -2:** 50th percentile hybrid III dummy FE model

50th percentile hybrid III dummy FE model	
Number of parts	152
Number of nodes	7,402
Number of elements	4,382
Number of materials	172
Number of joints	17
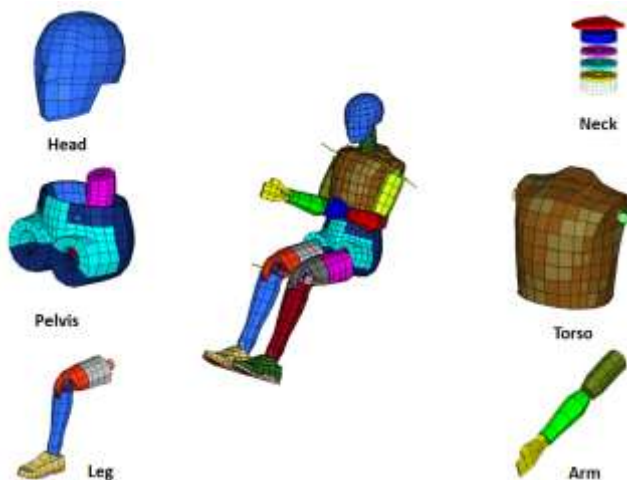
Fig -3: 50th percentile Hybrid III Dummy

2.5 INTEGRATION OF DUMMY WITH SEAT MODEL

The hybrid III 50th percentile male dummy was integrated with Seat model in LS-dyna pre-processor according to FMVSS 208. LS-dyna have two positioning operation one is H point and second one is Limb point.
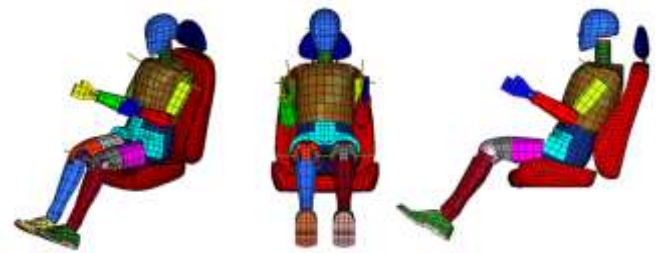
Fig -4: Dummy positioned with seat

2.6 PRE COMPRESSION IN FOAM

Compressing the seat is necessary if the dummy is to be positioned correctly.

Fig -5: Pre compression in foam

2.7 BOUNDARY CONDITION ON DUMMY

With the objective of understanding the behavior of human body as well as its effect during rear end crash of the car. The simulation was carried using the acceleration pulse defined by the Euro NCAP (European New Car Assessment Program) which covers the range of Speed from 16-24 Km/h.

2.8 SOLVER AND POST-PROCESSING

After applied boundary condition in our first case model, we need to export it in .k extension and solve it in LS-dyna solver, it will consumed some time to solve. Ones the run is finished, I will import in LS-dyna post-processor, now we can see the results as shown in figure. The large deformation in the neck was observed during crash, which shows first case design has failed.
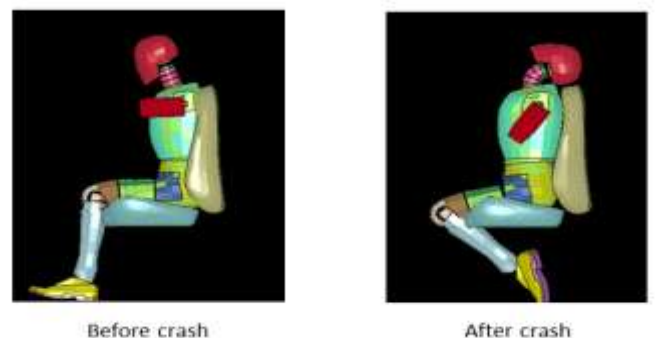
Before crash   After crash

Fig -6: First case results

3. DESIGN MODIFICATION

There are two possible modifications will perform according to manufacture requirements.

3.1 ADDITION OF THE HEADREST (SEAT 2)

After observing the last results, the possible of neck movement of dummy was found the headrest should be introduce in seat to support the neck. For that we use our second case design to perform the same analysis. This headrest will support the neck during crash as well as it will be comfortable for the occupant during long journey.
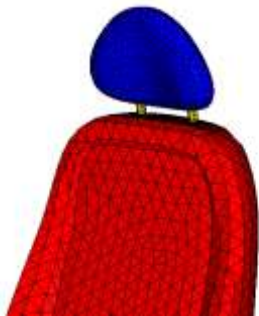

Fig -7: Headrest in seat model

The modified design again solved using LS-dyna solver, and observing the results in LS-dyna post processor, the neck deformation was less than previous one but not satisfactory.
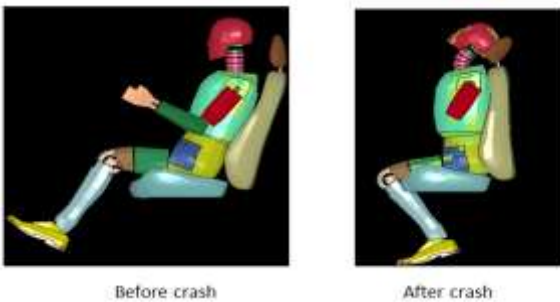

Before crash   After crash

Fig -8: Second case results

3.2 INCREASE IN HEADREST HEIGHT (SEAT 3)

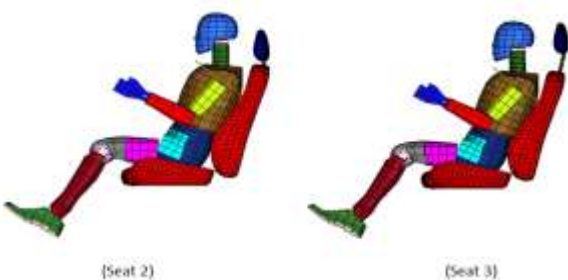In our third case it was decided to increase the height of headrest than previous one as shown in figure.

(Seat 2)   (Seat 3)

Fig -9: Increase in headrest height

After applied the same process, it was found that very less movement in neck and there was no injury.

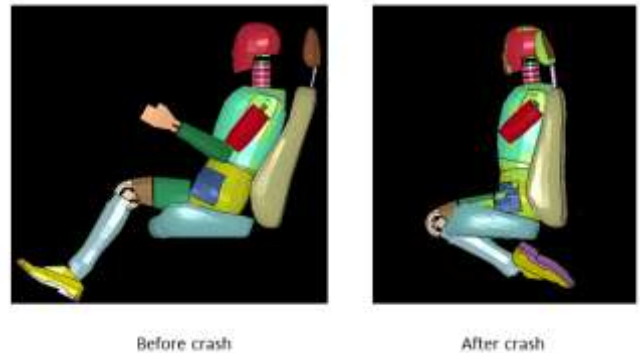
Before crash   After crash

Fig -10: Third case results

4. RESULT

There is a comparison between the initial seat design and final seat design, our first case is without headrest and the third case is with headrest.

With respect to displacement: - In this comparison we find out the behavior of dummy with respect to time.
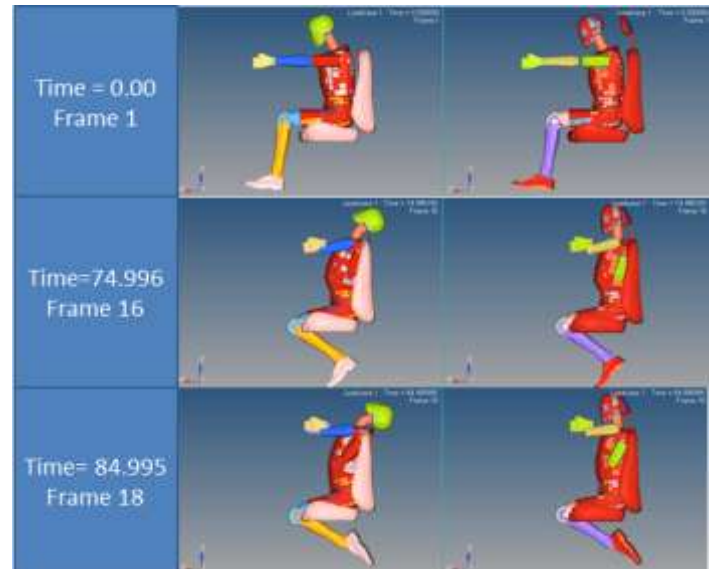

Fig -11: Comparison of the final seat design and initial seat design

With respect to neck displacement:- This comparison is based on neck displacement, you can see the maximum displacement in initial condition 347mm and in final condition is 174 mm.
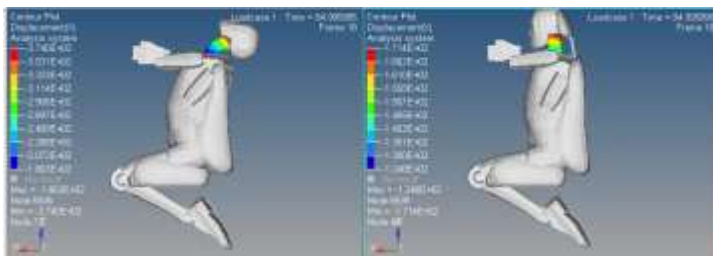
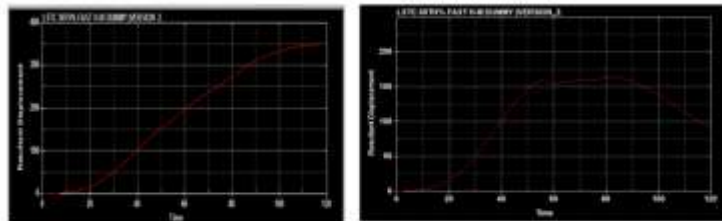**Fig -12**: Comparison of the Neck displacement

Fig -13: Graphical comparison of the neck

With respect to neck acceleration: - We can see the comparison in the neck acceleration in the figure 25, initially neck acceleration was around 32.98m/s^2and in final design it was 23.5m/s^2.
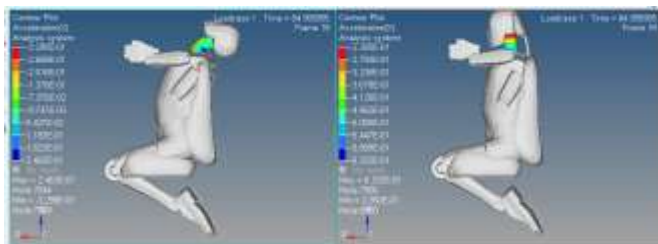

Fig -14: Comparison of the neck acceleration
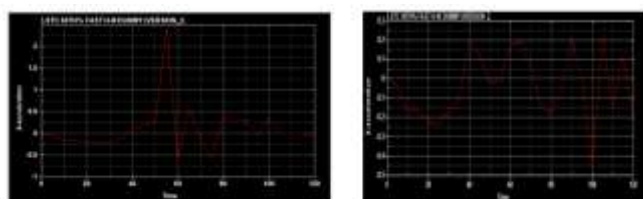

Fig -15: Graphical comparison of the neck acceleration

5. CONCLUSION

The displacement and acceleration of the neck has been reduced to a great extent by introducing the headrest in design. This approach can be generalized to any vehicle seat making them safer.

Optimum product design can be obtained by performing crash simulation and carrying out iterations virtually; development time has been reduced and also obviated the need to carry out expensive physical tests making the seat design cost-effective as well.

This simulation technology has greatly increased the protection of the occupants, dependability and producing potency in today's vehicles and will continue to do so in the future.

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