# Structural performance improvement of passenger seat using FEA for AIS 023 compliance

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***Abstract* - In this work structural performance of seat structure has been studied and improved to meet the Automotive Industry Standard (AIS)-023 regulations [5], using Finite Element Method (FEM) based numerical code. The base design was found to be not meeting the requirements in the test. The Finite Element Analysis (FEA) of base model was done to establish the correlation with the test results. The results of the base model in FEA were in close correlation with the test results validating the materials used and the test procedure followed. Later, the weak zones were identified and relevant design changes were made through hand calculations and then the design changes were implemented in the model. The main structural part which was circular in cross section was replaced by square section tube. Dimensions of the square tube were derived from hand calculations. Replacing the circular tube with square tube showed significant improvement in the structural performance of seat. The Seat was able to sustain the rated load and deflections were also found to be within the specified limits with no structural failures at any other locations.**

***Index Terms* - Structural analysis, Passenger seat, AIS 023, H1-H2 test**

**Nomenclature**

Б$_b$ Induced bending stress
M Bending moment
F Loads in kN
I Area moment if inertia
ȳ Distance from neutral axis
z Section of modulus

## I. INTRODUCTION

The Seat is the soul of automotive. Individual is specifically related to the vehicle through Seating System. The disappointment of seat framework directly affects on administration and guarantee claim cost. It is along these lines vital to outline and test Seat of vehicles for its quality from well-being perspective. [4]

## II. PHYSICAL TEST SET UP FOR BASE DESIGN

**Description**

III. Fig.1 shows the physical post test set up of seat & it was taken from the ARAI SSD test lab, Kothrud, Pune. H1-H2 test was done on the seat, which is fixed on the rigid fixture. H1- H2 loads were acting on the back frame of the seat. There are two electrical actuators which applies load on the seat. It has been done as per AIS 023 compliance. In the test, the back frame shows excessive bending. The Seat was not meeting the AIS 023 requirements. There are weak zones generated due to high stresses and not sustain the required load.[2]

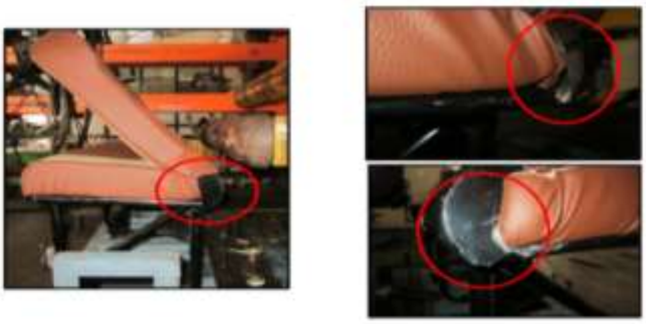


**Fig.1** Post Test set up

***Graph and results***

Fig .2 shows the test graph and results in the table, load vs. displacement graph shows the failure of the seat and it does not fulfill the requirement of AIS 023 compliance. The table shows load achieved and the displacements in the seat.

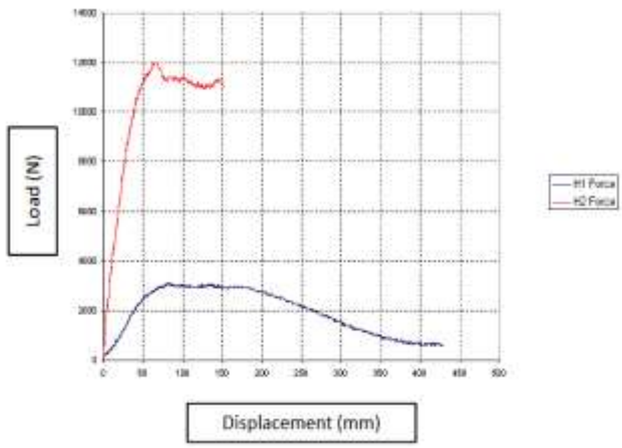



**Fig.2** Graph of physical testing

**Table .1** Results of physical testing [5]

| Sr. no. | Height of reference floor (mm) | Load to be applied (KN) | Displacement range as per standard(mm) | Load achieved (KN) | Displacement (mm) |
|---|---|---|---|---|---|
| 1. | H1-750 | 4.0 | 100 to 400 | 3.0 | 146 |
| 2. | H2-500 | 12.0 | More than 50 | 12.0 | 65 |

## III.SIMULATION OF BASE DESIGN

### Modeling view

Fig .3 shows the modeled seat; the seat was modeled as per AIS 023 compliance. For the modeling of seat, average mesh size of 6 mm, warpage of 15 degrees, and aspect ratio of 5 degrees and jacobian of <0.6 were used for the quality index.

For weld modeling, Rigid Beam Element (RBE2) was used and for bolt modeling beam element was used [6]. Automatic surface to surface contact is used in modeling.

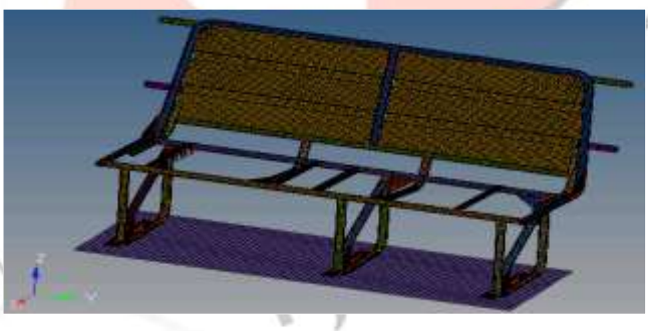


**Fig .3** FEA of base model

### Analysis

Fig. 4 shows analysis of the seat. The analysis was done using the LS-Dyna software. The Analysis also shows a failure of the seat at high-stress area. [1]

**Fig .4** Analysis of base design

### Graph & results

Fig .5 shows graph & results. In test and FEA stress, strain, displacement results were matched.

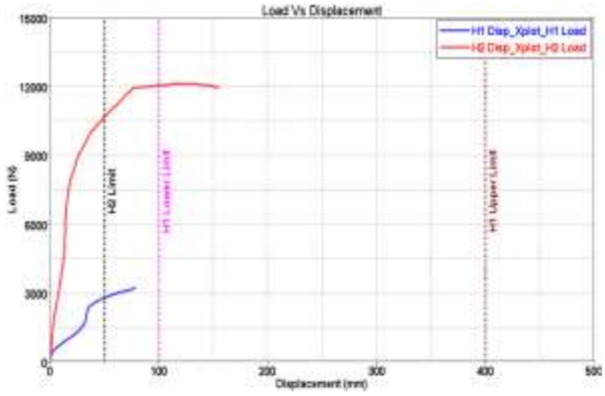



**Fig.5** Graph for base model

**Table 2.**Results for base model

| Sr. no. | Height of reference floor (mm) | Load to be applied (KN) | Displacement range as per standard(mm) | Load achieved (kN) | Displacement (mm) |
|---|---|---|---|---|---|
| 1. | H1-750 | 4.0 | 100 to 400 | 4.0 | 153 |
| 2. | H2-500 | 12.0 | More than 50 | 12.0 | 72 |

## IV. SIMULATION OF NEW DESIGN

### Design changes

Fig.6 shows parts of the seat like side gusset, cushion support tube, back panel, center back & cushion support are removed from base model. Mass of the frame was 19.3kg.

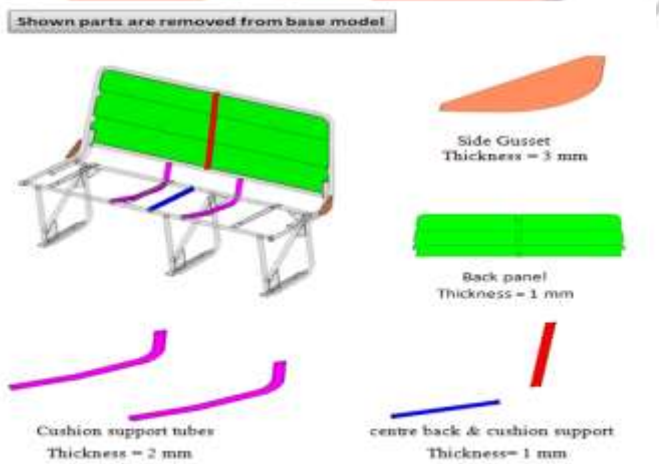



**Fig.6** Parts removed from base model

Fig. 7 shows new design of parts in the seat like gusset, square tubes, back strip (3 no.s) .The mass of new frame is 18.8kg. Mass reduction of 0.5kg is achieved. Circular tubes are replaced by square tubes. Square tube of side 30×30×2 is used.

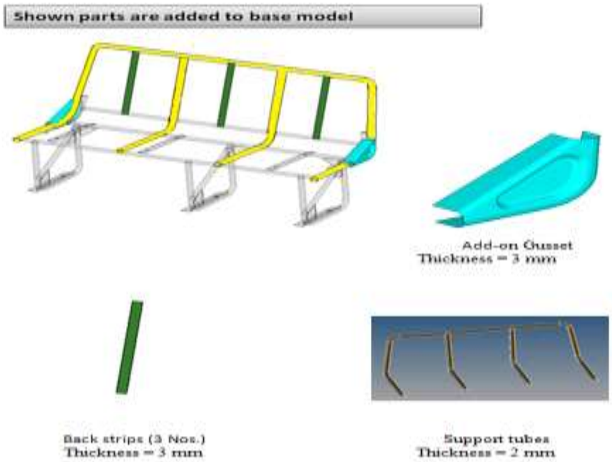



**Fig.7** Parts added in base model

**Hand calculations**

- Bending moment

$M = F_1L_1 + F_2L_2$ (1)
$= 12000*100 + 4000*50$
$= 1400000$ Nmm

- $b_1 = d_1 = 24$   $d_2 = b_2 = 20$ (2)

- Thickness

$T = (d_1 - d_2)/2$ (3)
$= 4/2$
$= 2$ mm

- Section of modulus (4)

$$Z = \frac{I}{y} = \frac{\frac{b_1 d_1^3}{12} - \frac{b_2 d_2^3}{12}}{\frac{d_1}{2}}$$

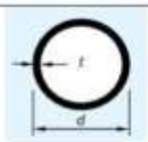
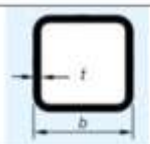
$= 2520.69 - 60.703$
$= 2460.65$

- *Bending stress*

$бb = M / 2Z$ (5)
$= 1400000/4921.3$
$= 284.47$ N/mm$^2$

**Comparison between circular & square tube**

**Table .3** Comparison of circular & square tube

| Sr. No. | Factors | Circular tube | Square tube |
|---|---|---|---|
| 1. | Shape |  |  |
| 2. | Dimensions(mm) | Inner dimeter-20 Outer dimeter-17 | Inner dimeter-24 Outer dimeter-20 |
| 3. | Moment of inertia ($Nmm^4$) | 1456.86 | 14314.66 |
| 4. | Section of modulus | 145.68 | 2460.65 |
| 5. | Induced bending stress($N/mm^2$) | 480.7 | **284.47** |

Bending stress is found to be less in square section, so it is used.

**Analysis**

**Von –mises stress**

Fig. 9 shows von mises stress, it is based on distortion energy failure theory, it is used for ductile material. The criteria for failure, shear strain energy for multiaxial loading is equal to the shear strain energy at yield point for the uniaxial test.[6] Permissible stress was 425.0 $N/mm^2$ and dynamic maximum value was 391.0 $N/mm^2$.The stresses formed in the seat were within a limit and displacement was also within a limit. Seat design was safe and it is compliant with AIS 023.

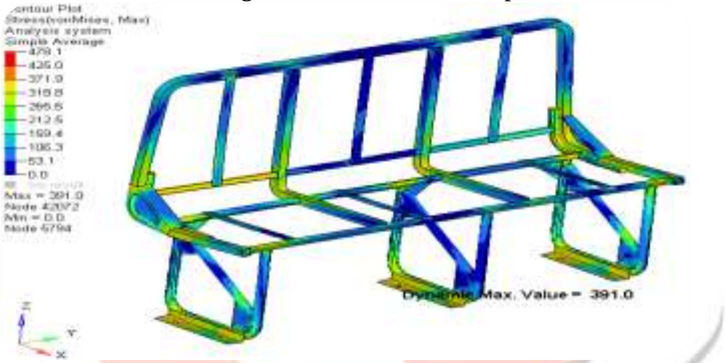



**Fig.8** Von- mises stress

**Effective plastic strain**

Effective plastic strain develops at whatever point the material is effectively yielding i.e. whatever the point of stress on the yield surface. The Effective plastic strain is similarly expanding scalar quantity which is figured incrementally as an element of Dp (ij), the plastic part rate of distortion tensor. [6]

Permissible strain for the seat was 0.280 and dynamic maximum value was 0.218.

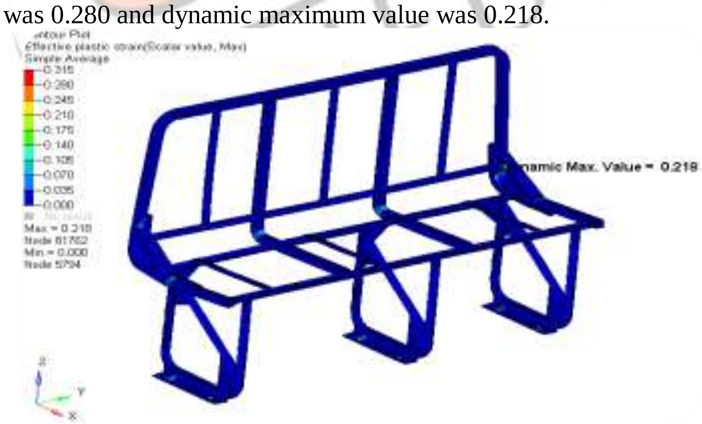



**Fig.9** Effective plastic strain

**Graph and results**

Fig. 10 shows the graph and results; it shows the simulation results are within the limit and follows the AIS 023 compliance. There was no failure like the previous simulation and it gives better results.

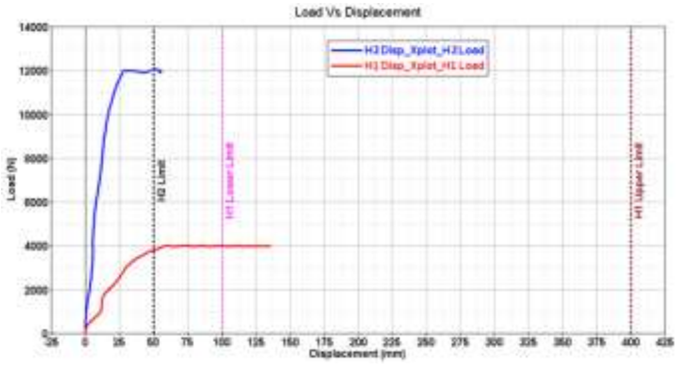



**Fig .10** Graph for square section design

**Table .3** Results for square section design

| Sr.No | Height from reference floor (mm) | Load applied (KN) | Displacement range as per standard (mm) | FEA Displacement(mm) |
|---|---|---|---|---|
| 1 | H1 - 750 | 4 | 100-400 | 135.7 |
| 2 | H2 - 500 | 12 | More than 50 | 57.3 |

## V. RESULTS & DISCUSSIONS

FEA & testing results were validated by physical testing and it shows in the fig.12. From the results,displacement of the seat was nearly equal to the test & FEA. The difference between test & the new simulation is FEA simulation sustain the load of 4 KN and 12 KN and gives results within limit but the test seat has not sustained the load of the elecrical actuator.

**Table .11** Results of test & simulation

| S.No. | Height from reference floor (mm) | Load applied (kN) | Displacement range as per standard (mm) | Test | | FEA (Base Design) (D0) | | FEA (D1) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Load Achieved (KN) | Displacement (mm) | Load Achieved (kN) | Displacement (mm) | Load Achieved (kN) | Displacement (mm) |
| 1 | H1 – 750 | 4 | 100-400 | > 4 | 146 | 4 | 153 | 4 | 135.7 |
| 2 | H2 – 500 | 12 | More than 50 | > 12 | 65 | 12 | 72 | 12 | 57.3 |

Table. 11 shows the bar graph of comparison between test & simulation, graph validates the test & FEA results.

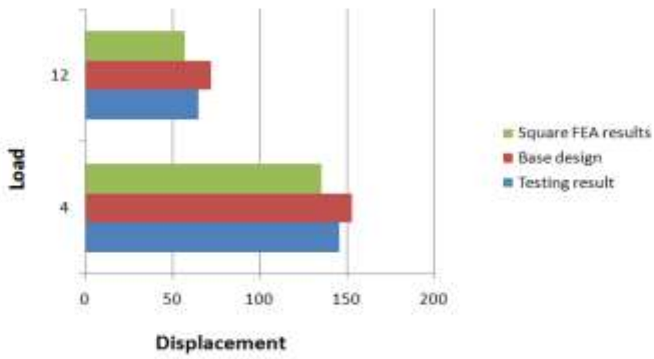



**Fig .12** Bar graph comparison

## VI. CONCLUSIONS

- Base design #D0 was not able to withstand the rated load as per AIS023 (H1, H2 TEST). Back structure collapses for the applied load. Mass of frame was 19.3kg.

- Design #D1 withstands the rated load as per AIS023 (H1, H2 TEST). Deflections were also within the specified limits. The mass of frame was 18.8kg. Mass reduction of 0.5kg was achieved.

## VII. ACKNOWLEDGEMENT

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## REFERENCES

[1] Biswanath Nandi, Dinesh Jain. "Prediction of seat deformation in a rear crash using LS-DYNA" proceedings of the 8th international LS-DYNA user conference Lear corporation, Southfield Michigan, USA.

[2] P. Baranowski, K. Damaziak. "A child seat numerical model validation in the static and dynamic work conditions." Military University of Technology, 2 Gen. Kaliskiego Street, 00-908 Warsaw, Poland, (2015).

[3] Zhigang Li, Hao Ge, Jinhuan Zhang" The necessity of evaluating child in a frontal collision of a school bus for transportation safety." Tsinghua University, No. 1 Tsinghua Yuan, Haidian District, Beijing 10084, China. Safety Science 62 (2014) 441–449

[4] Mulla Salim H., Yadav Sanjay D., Dhananjay Shinde "Importance of Federal motor vehicle safety standards 207/210 in occupant safety-case study". RIT Sakharale Islmapur 415414, India. Procedia Engineering 64 ( 2013 ) 1099 – 1108

[5] Amendment no.2 ToAIS-023 Automotive Vehicles - Seats, their Anchorages and Head Restraints for Passenger Vehicles of Categories M2, M3 and Goods Vehicles of Category N – Specifications

[6] Nitin s Gokhale, "Practical Finite Element Analysis" Finite to Infinite, pune. .