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Performance Enhancement of School Bus Seat as per AIS-023 through FEA and Validation

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ABSTRACT

The seating system is a very important system in an automotive and it plays an important role as it directly influences human comfort. Human being is directly related with the vehicle through seating system. The seating system is one of the most expensive systems in any vehicle. The failure of seating system has a direct impact on service and warranty claim cost. In this paper, simulating the H1, H2 test on bus seat to determine it's bending strength and modifying the design to pass AIS-023 test. The CAD geometry of 3 leg seat is prepared using CATIA and is pre-processed by using HYPERMESH software. The simulation is carried out by using LS-DYNA software to evaluate the seat to satisfy the requirements mentioned in automotive industry standard 'AIS-023'. The result of the FEA analysis is compared with the experimental result.

Keywords— Seating system, H1, H2 Test, 3 leg seat, AIS-023, FEA, Analysis

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I. INTRODUCTION

A large number of accidents take place every year which causes severe injuries to the passengers. Bus safety is a major concern in many developing countries where bus transport plays an important role in assuring accessibility to the majority of population. High rate of accidents have been reported for buses as compared to other types of vehicles in many developing countries like India, Nepal, Tanzania, Sri Lanka, Pakistan and Bangladesh. Seating system is a very important system in an automotive. The seating system plays an important role as it directly influences human comfort. Human being is directly related with the vehicle through seating system. The seating system is one of the most expensive systems in any vehicle. The failure of seating system has a direct impact on service and warranty claim cost. It is therefore important to design and test seat of an automobile for its strength from safety point of view. Seat, seat belts and seat belt anchorages etc are critical for the passenger in case of sudden accelerations or decelerations and also during an accident or in the event of frontal crash. The most important function of seatbelt is to protect head and body of the wearers in frontal impact since majority about 60% serious and fatal injuries occur in such accidents.

According to national automotive sampling system (NASS) the data collected shows that, around 57% crashes out of total crash are of frontal crash and is a reason for major head injuries. A seat belt also reduces severity of the injury in other circumstances also, but they are primarily designed to protect against injury in head-on collisions and frontal impacts. Other advantage of seat belt is that, it greatly reduces the forces which act on the whole body to bring it to the rest. With no seat belt, the head and body are brought to rest by striking hard and unyielding objects, giving rise to very large forces acting over very short time;

this may cause serious injury to the occupant. In order to ensure the strength of seats,

seat belts and anchorage points, several regulations have been implemented and different tests are performed according to those regulations. Various regulations have been defined by different agencies across the world in different countries. The seat to be used for Ashok Leyland Lynx School bus was found to be failing during the test performed according to the standard AIS-023. The seat back shown excessive bending and design changes were required to reduce the bending and make the seat pass the test. In the event of an accident such as frontal crash due to sudden stoppage of vehicle, the seat occupants may collide on next seat and also there is a possibility that due to the momentum gained the seat back structure may bend. In order to avoid injury to the seat occupant, the seat structure must have sufficient bending stiffness to avoid excessive bending of seat back structure. The effect of modifications will be studied and discussed. The result of the FEA analysis will be compared with the experimental result.

A. OBJECTIVES

1. To simulate the H1, H2 test on bus seat to determine its strength.
2. To modify the failed design in order to pass the test.
3. To compare the FEA result with experimental result.

B. METHODOLOGY

1. Review of Indian automotive industry standard (AIS-023).
2. Prepare the CAD geometry using CATIA software.
3. Pre-process the CAD model using HYPERMESH software.
4. Simulate the mesh model using LS-DYNA software.
5. Determine the weak section, weak zone and suggest modification to improve strength.
6. Validate FEA result with experimental result.

II. THEORY

In this topic, some important points have been discussed which are useful in the bus seat analysis.

C. H1, H2 Test

H1, H2 indicates heights of forces from a reference floor at which H1, H2 forces are applied. Here, H1 is 750mm and H2 is 500mm. Also the values of forces are 4kN and 12kN. During testing, the seat floor always fixes in all degrees of freedom and forces apply at height 750 and 500mm. As per automotive industry standard (AIS-023) this testing is conducted.

Fig. 1. H1, H2 Test

D. Automotive Industry Standard (AIS-023)

It is the standard used for seat, seat belt, their anchorages and head constraints of the passenger vehicle and good vehicle. Here, the bus seat analysis is analysed with the help of AIS-023. As per this standard the loads of 4kN and 12kN is selected for the bus seat analysis.

E. 3 Leg Seat

The seat with 3 legs is said to be 3 legs seat. In this analysis, the bus seat is fixed in all degrees of freedom. The forces of 4kN and 12kN are applied from heights of 750mm and 500mm respectively. The bending strength of the seat is analysed under the load application. The experimental model of 3 leg seat is shown in figure 2.

Fig. 2. 3 Leg Seat

F. Material Properties

Material properties that are used in a bus seat analysis are listed below.

1. Yield Strength
   It is the maximum stress that can be developed in a material without causing a permanent deformation.
   Here, yield strength of tube is 328.6MPa and that of HR sheet is 360MPa.

2. Tensile Strength
   It is the ability of a material to resist breaking or tearing under tension. Here, tensile strength of tube is 363MPa and that of HR sheet is 475.8MPa.

3. Percentage Elongation
   It is the ability of the material to stretch up to its breaking point. Here, maximum elongation of tube is 32% and that of HR sheet is 37%.

III. FINITE ELEMENT ANALYSIS

Based on a seat as research subject, the HYPERMESH and LS-DYNA simulation software is used to build a seat-occupant finite element model. The main purpose of this study is to analyse the performance of the seat and to modify the failed structure. The base design of a seat will be analysed to identify the weak zone. Further the physical H1, H2 test on a seat will be conducted to make sure displacement with respective to given load within allowable limit.

G. CAD Model of 3 Leg Seat

Figure 3 shows the CAD model of 3 leg seat. This CAD model will be used in HYPERMESH for pre-processing.

The seat structure is the main geometry require for the analysis.

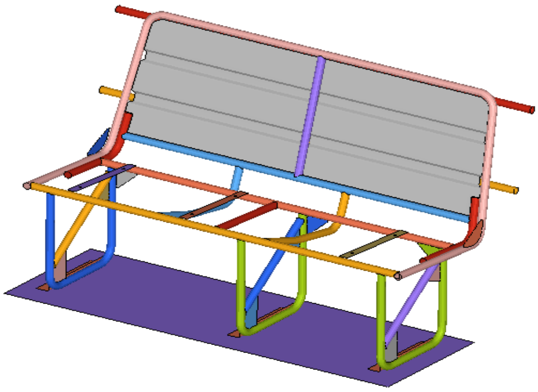


Fig. 3. CAD Model of 3 Leg Seat

H. Mesh Model of 3 Leg Seat

Figure 4 shows the mesh model of 3 leg seat. This mesh model will be used in LS-DYNA for post-processing. Pre-processing includes geometry cleanup, meshing of seat structure, modelling of joints, material data input and defining boundary conditions.

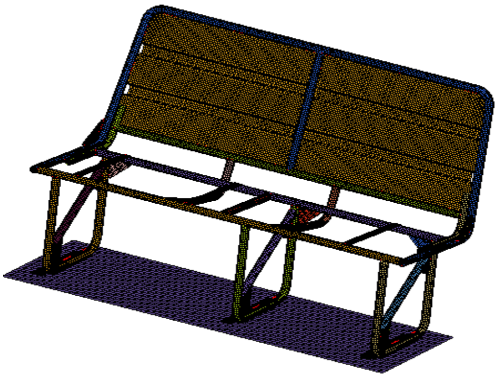


Fig. 4. Mesh Model of 3 Leg Seat

Model is discretized with shell elements. The average size of element is 5.0mm. The connections are used in this model are 1D rigid elements.

I. Material Details

Material properties for tube and HR sheet is given,

Tube: YS= 328.6MPa
TS= 363MPa
Max. Elongation= 32%

HR sheet: YS= 360MPa
TS= 475.8MPa
Max. Elongation= 37%

J. Loading and Boundary Conditions

The loading and boundary conditions are acting on seat is as shown in figure 5.

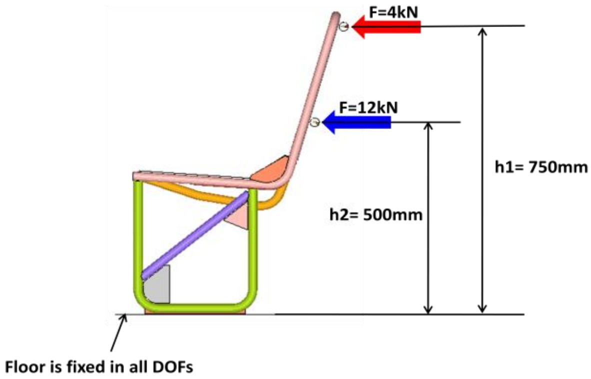


Fig. 5. Loading and Boundary Conditions

Here, forces 4kN and 12kN are acting on a seat at height 750mm and 500mm respectively. Seat is fixed on floor in all degrees of freedom. The deformations in seat will be analysed by using simulation software.

K. Deformation Plot

The deformation plot for bus seat is as shown in figure 6. The back structure is collapsed for the rated load. Deflections are exceeding the specified limits. Also, the back structure is not sustained the load of 4kN. The collapsed structure of a vehicle seat is shown in figure 6.

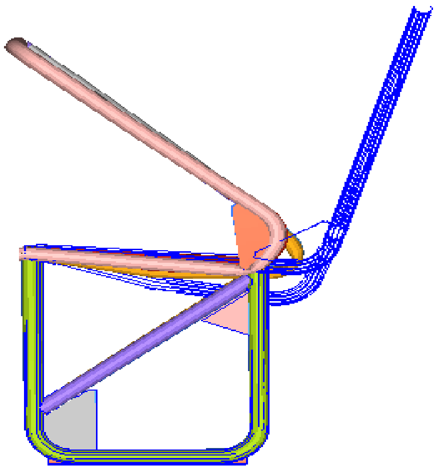


Fig. 6. Deformation Plot for 3 Leg Seat

This is the failed structure of a bus seat. Now, the modified seat will be designed for the next analysis. From FEA analysis it is clear that the design is failed in bending. Now, the next seat will be designed to improve the bending strength and will sustain the load of 4kN from height 750mm.

The collapsed structure of the seat is shown in figure 7.

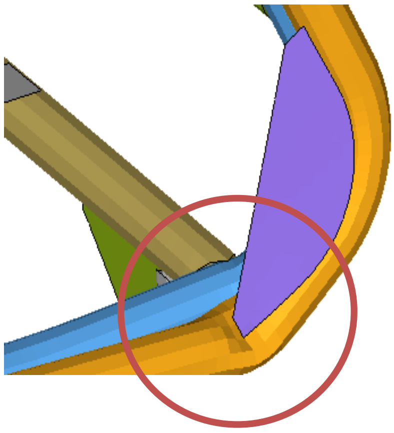


Fig. 7. Collapsed Structure of Seat

This collapsed structure failed in an excessive bending. Now, this collapsed seat is to be modified to improve bending strength.

L. Experimental Analysis

The experimental analysis of a bus seat has been performed as per automotive industry standard (AIS-023). Here, the seat fixed to the floor and the forces were applied through pneumatic cylinder. The forces of 4kN and 12kN were applied at height 750mm and 500mm respectively.

1. 3 Leg Seat Specimen
   The 3 leg seat specimen used for experimental analysis is as shown in figure 8.

Fig. 8. 3Leg Seat Specimen

Here, the seat is fixed to the floor and is prepared for experimental analysis.

2. Pre-Test Setup
   The setup used for 3leg seat analysis is as shown in figure 9. Here, two pneumatic cylinders were arranged at height 750mm and 500mm.

Fig. 9. Pre-Test Setup

3. Post-Test Result
   Here, the back structure is collapsed for the rated load. Deflections are exceeding the specified limits. The structure is not sustained the load of 4kN applied from 750mm height. The collapsed structure of a bus seat is shown in figure 10.

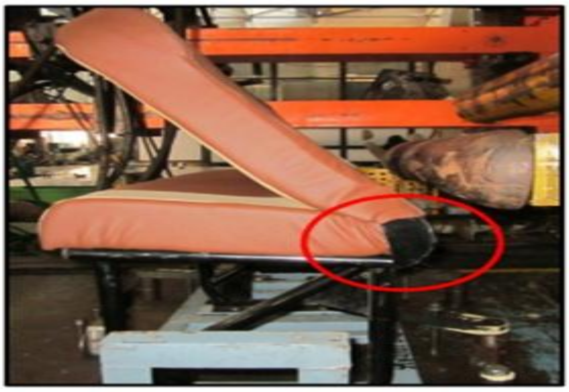


Fig. 10. Collapsed Structure

The load versus displacement graph for 3 leg seat is as shown in figure 11. Here, loads plotted on x-axis and displacements on y-axis.

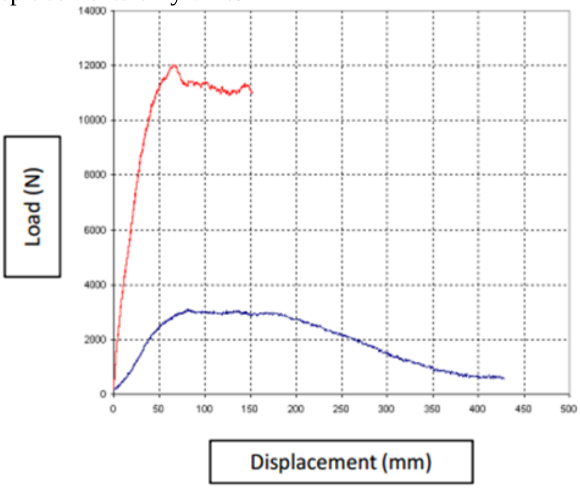


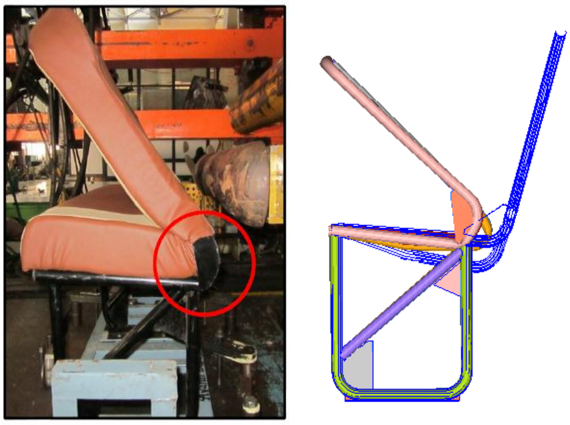
Fig. 11. Load Vs Displacement graph

The experimental result of the structure is given in table 1 below.

Table 1. Experimental Result of the Structure

Height from reference floor (mm)	Load applied (kN)	Displacement range as per standard (mm)	Load achieved (kN)	Displace-ment (mm)
H1-750	4.0	100 to 400	3.0	NA
H2-500	12.0	More than 50	12.0	65

4. Comparison of Experimental and FEA Result
   The experimental and FEA analysis is compared here for their deflections. From these analyses, it is clear that the bus seat fails in excessive bending. Both these analysis shows the excessive bending in the seat. Now, the aim is to modify the structure to improve the strength of the seat.



Test Result FEA Result

Fig. 12. Comparison of Experimental and FEA Result

M. Modified Design Analysis

The bus seat used for analysis is failed in an excessive bending. Now, the aim is to modify the base structure to pass the H1, H2 test. Here, the modified design of seat structure is shown in figure 13. In this design, the side gusset, back panel, cushion support tubes and centre backs are removed from the base structure. The mass of the base structure is 19.3kg. In modified design, side gusset with 3mm thickness, support tubes with 3mm thickness and the back strips with 3mm thickness are added. Now, the mass of seat structure is 18.kg.

1. Modified Design
   The modified design of the bus seat is shown in figure 13. Here, the back panel is removed and back strips are added to make the backrest strong.

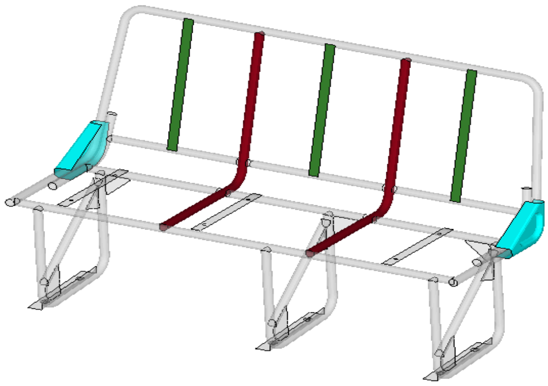


Fig. 13. Modified Design

Now, this modified design will be analysed in simulation software to check whether the seat fails or pass. The analysis of modified design is given below. The deformation plot, stress plot, strain plot of the modified design given below. This analysis shows the backrest holds the load of 4kN and deflection is also within the limit. The finite element analysis of the modified design shows the deflections are within the specified limit. The stresses and strains are also within the ultimate limit of the material. Here, the base design and modified design will be compared for their displacement.

2. Deformation plot
   The deformation plot for modified design is shown in figure14. Here the backrest holds the load of 4kN. The deflections are also within specified limit.

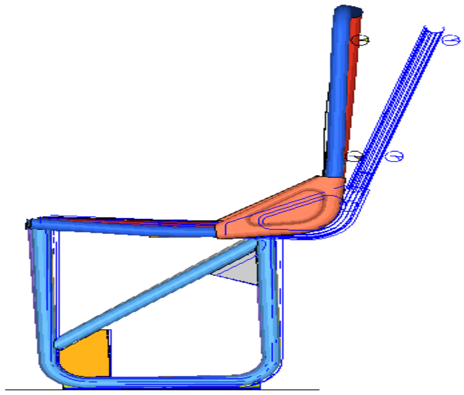


Fig. 14. Deformation Plot

3. Stress Plot
   The stress plot for modified design is shown in figure15. The maximum stress is 412.6MPa on the mounting bracket which are within the ultimate limit of material (485MPa).

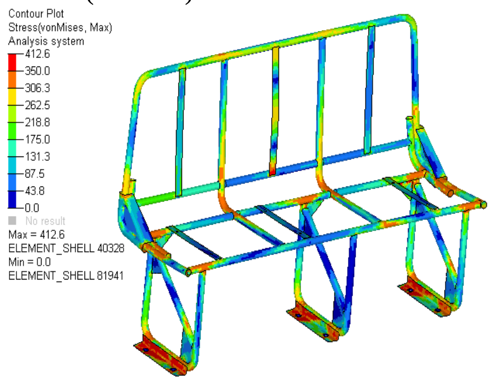


Fig. 15. Stress Plot

4. Strain Plot
   The strain plot for modified design is shown in figure 16. The maximum strain is 0.222 on the mounting the mounting bracket which is within the ultimate limit of material (0.37).

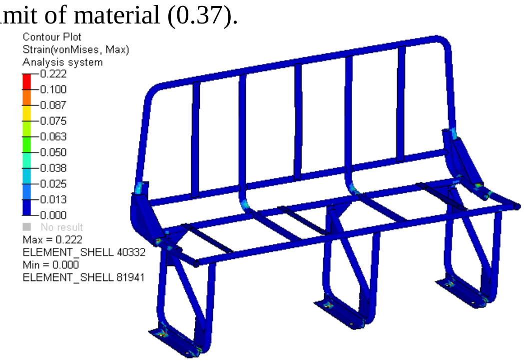


Fig. 16. Strain Plot

Load versus displacement graph for the modified design is shown in figure 17. This graph shows the deformation of seat is in a specified limit and the design is safe as per automotive industry standard.

5. Load Vs Displacement Graph
   The load versus displacement graph for the modified design is shown in figure 17.

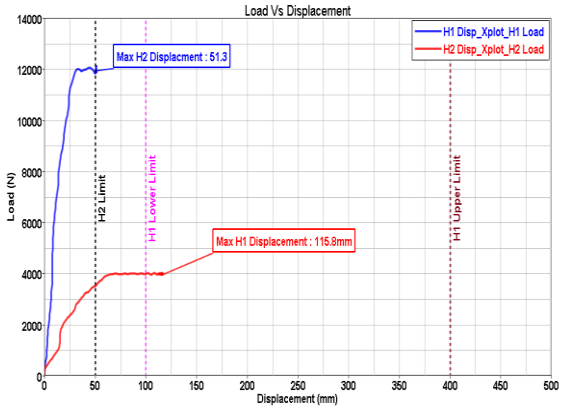


Fig. 17. Load Vs Displacement graph

6. Comparison of base design and modified design

Table 2. Comparison of base design and modified design

Base design		Modified design	
Load achieved (kN)	Displacement (mm)	Load achieved (kN)	Displacement (mm)
3.0	NA	4.0	115.8
12.0	65	12.0	51.3

VI. CONCLUSION.

Conclusion of this paper comprises of performance enhancement using finite element analysis, improvement in the bending strength, reduction in the cost of seat failure, improvement in the safety of the passenger, optimization and design modification is also included in the conclusion of this paper.

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