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Review Article

Finite Element Analysis of School Bus frame structure as per AIS029 Pendulum Impact Test using LSDYNA

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Abstract *- According to the ministry of road transport in India, there are 1.5 million schools and around 260 million school-going children, and over half of them use school bus transportation facilities to travel from or to school. In short, school buses are one of the most important transport vehicles for school students, but according to the world health organization report, road accidents are the primary reason for death in the age group 5-29 years. India ranks at the top with the highest fatalities, with 11% of the total share in the world. There are many reasons for fatalities like speed, non-use of a safety system, and unsafe road infrastructure, but the fundamental reason is unsafe vehicle structure. According to school bus accident statics, frontal collision is the most hazardous in comparison with all other accidents because frontal structures get damaged easily, and this will lead to death and injury of the driver and crew member, which are the key persons in controlling the vehicle and ensure the safety of others. In this research work, we performed a pendulum test on the school bus superstructure as per AIS029 using LS-Dyna explicit solver.*

Keywords - *Explicit Solver, Fatalities, Frontal collision, Superstructure.*

1. Introduction

In India, about 2.1% of Indians have two-wheelers, and 4.7% of people own four-wheels; all other Indians use the bus as a mode of public transport [1]. A few years ago, most of the schools were situated in the city near the townships, and school transportation facilities were not needed, but in the current scenario, due to space constraints, schools are shifted outside of the city followed by highways, and school buses are used to travel but the school buses not designed and tested as per highways. A good road is essential for rapid growth; it provides the facility to connect or expand business and investments. Ministry of road transport and highways ensure to develop and maintain road network, mainly working on national highways. The primary road statics is an annual publication related to the transportation sector by the ministry of road transport and Highway. As per the basic road statics of India 2018-19 report, India secures its position as second in the world with over 5,897,671 kilometers of the road network, of which national highways contribute around 1.94%, state highways contribute around 2.97%, District Road contribute around 9.94%, rural road contribution around 70.65%, Urban Road contribution around 9.27%, and project road contribution 5.58%. [1].

The Indian Road network is one of the busiest in the world in terms of traffic. Our automotive sector is in the fourth position in Asia, with around 3 million new vehicles registered in 2019. The number of accident fatalities in the Indian road network was around 449,002 at the end of the 2019 calendar, in which around 151113 people lost their lives, and around 451361 were injured [2]. Road accidents have become a major issue for the public as well as the government of India. The gross rate increased by around 1.3 percentage higher than the previous year; to control that percentage Indian government invests 3 to 5 percent of GDP every year.

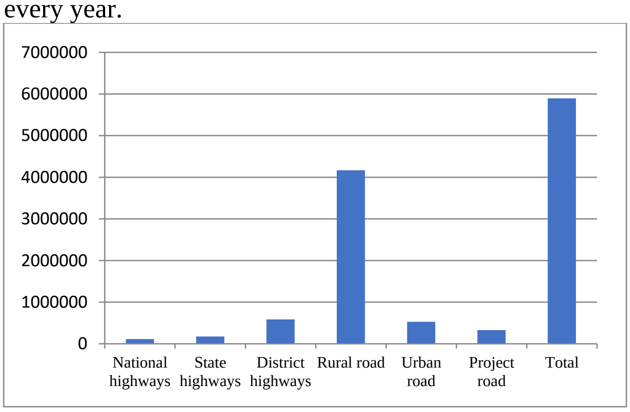

Fig. 1 Indian road network (Morth)

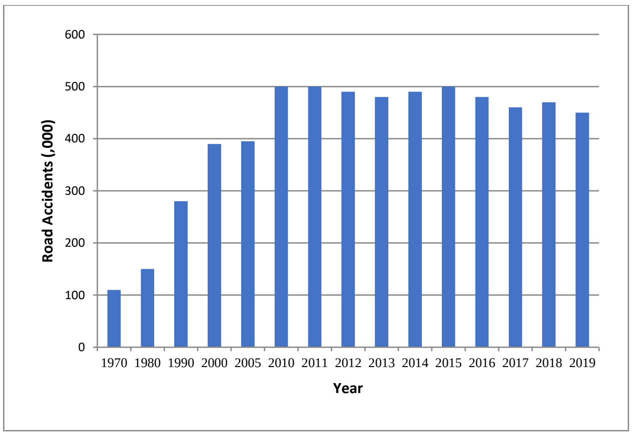

Fig. 2 Accident Static from 1970 to 2019 (Morth)

According to the world health organization, there are eight leading causes of death, [2] the first largest cause of death among children aged 5-14 and adults aged 15-29in which most school-going children use school bus transportation.

[3] AIS 029 standards generally specify the requirements of survival space for commercial vehicles [3]. This standard shall be subjected to by the vehicle manufacturers or truck body builder choice, either to perform all tests as per standard or only to performer test A and test B. Vehicle of category N1, derived from M1, means those types of vehicles have a pillar in a front structure similar to M1. Frontal impact tests shall only conduct on forward control vehicles. A standard should not apply to agriculture and construction vehicles. According to this standard vehicle, the structure shall be designed to eliminate the greatest possible extent of the risk of injury to the occupant in the event of an accident.

While preparing AIS 029 standard considerable assistance is derived from UNECE R29.

Test Requirement

1. Our vehicle mass is more than 7000 kg, so the pendulum impact energy should be 45kj
2. To achieve energy, a rigid rectangular Pendulum size should be 2500mm X 800mm with a mass of 1500 kg ± 250.
3. The pendulum is suspended by two rigid bodies 1000mm apart and 3500mm long.
4. The Centre of gravity of the rectangular surface should come 50 ±5/0 mm below the R-Point of the driver's seat.
5. To meet the test requirements, there should be no intrusion between the manikin and vehicle structure and no failure on mounting points.

The angular velocity 'ω' can be calculated by given formulas to achieve 45kj energy –

The total mass of the pendulum - M

Moment of inertia about the y-axis of rotation – ICOG_YY

Pendulum CoG height from the axis of rotation - h

Calculate Offset moment of inertia - ICOG_YY + M * h2

Kinetic energy will be

E = 1/2 IRA ω2

Where - ω is the angular velocity (rad/ sec)

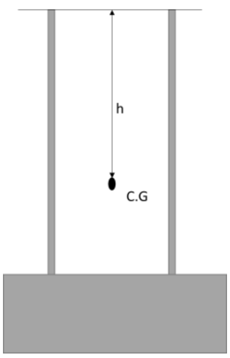

Fig. 3 Boundary condition

2. Materials and Methods

The finite element model of the bus and chassis structure was developed using a hypermesh preprocessor as per the LS-Dyna environment. Parts for which we do not want to evaluate stress or fracture are modeled as outer face 2D and assigned rigid material, but mass captured as per actual for dynamic analysis, which must be connected with deformable members by extra node contact card. The deformable components are modeled as 2D shell elements up to 4.5mm thickness; otherwise, use Hexa type of elements and assign nonlinear material properties using a MAT24 card. The pendulum is modeled as a rigid body using the MAT20 card. For this test, the driver seat shall be adjusted at a rearmost position, and a rigid dummy is positioned at the driving position to the R point.

Material properties are assigned to subparts as per IS 4923, as shown in the table below.

Table 1. Material property of bus superstructure

Part	Material	Yield Stress (Min)	Tensile Strength (Min)
A pillar	YST 310	310 Mpa	450 Mpa
Cant Rail	YST 310	310 Mpa	450 Mpa
Windows Rail	YST 310	310 Mpa	450 Mpa
Scott Rail	YST 240	240 Mpa	410 Mpa
Front Member	YST 240	240 Mpa	410 Mpa

Experimental data always considered an original cross-section area of the specimen; in finite element analysis, it is necessary to convert engineering stress-strain into a true stress-strain curve by considering the deformed state of the specimen. Analytical equations for converting engineering data to a true stress-strain curve.

True strain – Ln (1+ Engineering Strain)

True stress – (Engineering Stress) (1+ Engineering Strain)

EPS – True Stain – True Stress/E

The rigid pendulum is freely suspended by two beams placed at 1000 mm part and 3500mm long from the axis of suspension. The pendulum impact is horizontal and parallel to the median longitudinal plan of the vehicle. To achieve an impact energy of 45kj, we applied angular velocity using the initial velocity control card.

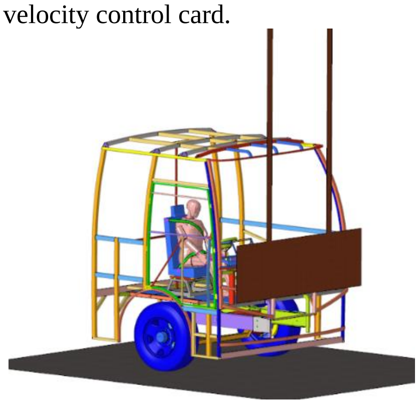

Fig. 4 Loading Condition

3. Results and Discussion

3.1. Baseline Design

Failure area is identified using strain contour in the hyperview post-processor, which is very high at chassis mounting locations, and there is no sufficient survival space between the steering structure and manikin.

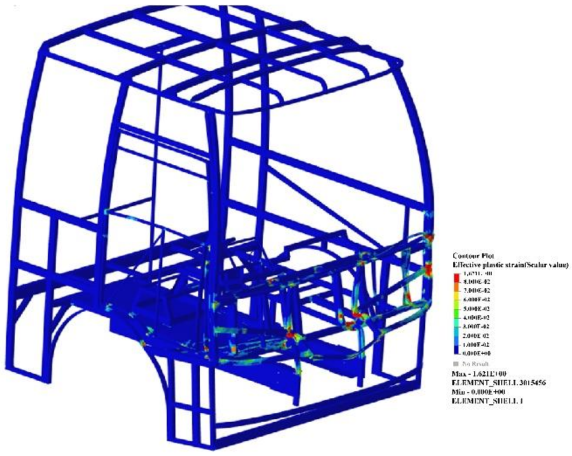

Fig. 5 Results

According to the law of energy conservation in crash analysis, the energy is neither created nor destroyed. It can be transferred from one form to another without changing the total amount of energy. It should be constant. The energy balance curve ensures simulation accuracy. As shown in figure 6, total energy should remain constant. Loss of kinetic energy will be compensated by internal energy, sliding energy, and hourglass energy. Hourglass energy should not be more than 5% internal energy, and sliding energy must be positive. The energy ratio must be in a range of .95 to 1.05.

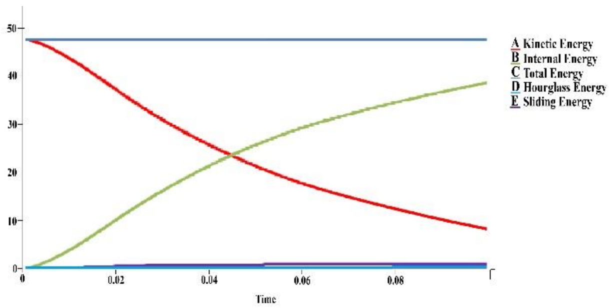

Fig. 6 Energy balance curve

3.2. Improved Design

To avoid failure, we developed a small crumple and updated all materials grades to yst310 from yst240.

After design modification, we found less deformation as compared with the baseline model and maximum survival space, which meet the testing Standard requirement**.**

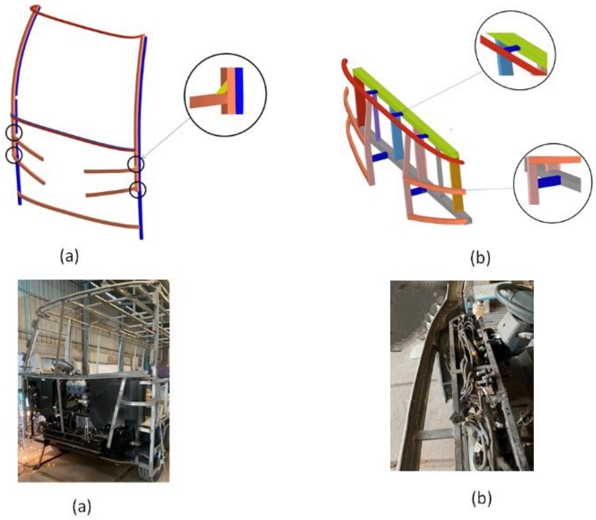

Fig. 7 Design Modifications

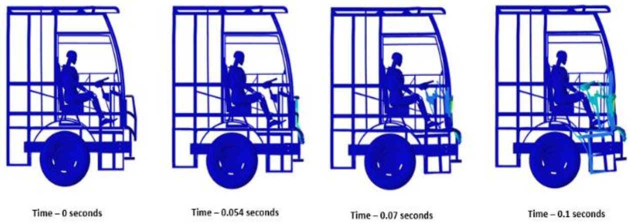

Fig. 8 Survival Space

The comparison of survival space between baseline and modified design

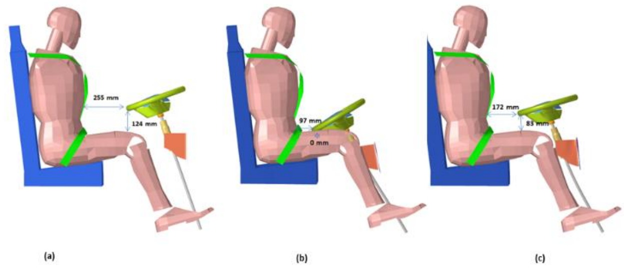

Fig. 9 Survival Space Comparison

4. Conclusion

The pendulum test as per AIS 029 standard tested on Bus superstructure using hypermesh and LS-Dyna explicit code was carried out successfully. We found very less survival space between the manikin and the bus superstructure. To avoid that failure and eliminate the risk of injury to the occupant, we developed a small crumple zone and updated the material in front of members, which helped reduce force by increasing the collision time. It was concluded that the risk of injury is very less after design modifications, and there is enough survival space after impact.

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