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Performance Improvement of Bus Structure for Rollover Analysis Using FEA and Validation of Roll Bar

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Abstract: *This paper discuss case of vehicles rollover crash, where bus structure needs to be strong enough to ensure the minimum damage. Finite Element modelling of the entire bus structure was done using pre-processor HyperMesh. Finally simulation was carried using LS-DYNA explicit solver. In this work, numerical simulation of bus rollover test using finite element method is followed. Simulation was done to show that the improved the crashworthiness performance of bus superstructure for rollover analysis. To improve strength and stiffness requirements of bus structure and to avoid above problem, we need to add stiffeners at side pillars. The experimentation for finding the peak load carrying capacity and peak deformation for M.S. (mild steel) was done by using three point bending test on rectangular cross sectional roll bar and validating its results using FEA.*
Keywords: *Bus Rollover, Finite Element Analysis (FEA), LS-DYNA, Residual space, Tensile Test, Three-point Bending Test.*

I. Introduction

Among the various modes of vehicle crashes, rollover crashes are often very severe and threatening to vehicle occupants. Hence The Automotive Industry Standard (AIS-031) in India specifies the requirements and methods to calculate the strength of superstructure of buses during and after rollover.In rollovers, passengers can be ejected, partially ejected, or become the victims of roof intrusion. The importance of bus crashworthiness against rollover accident in Indonesia can be emphasized by looking at Fig. 1, which reveals recorded accident data throughout the year of 2008 to 2010. As shown in Fig. 2, rollovers in buses are the leading cause of severe injury and death to their occupants. Today the European regulation “ECE R66” (Economic commission for Europe) is in force to prevent catastrophic consequences of such roll-over accidents thereby ensuring the safety of bus and coach passengers. AIS 031 is for rollover setup. The aim of this study was to investigate the impact on passenger residual space as per AIS 031 regulation.

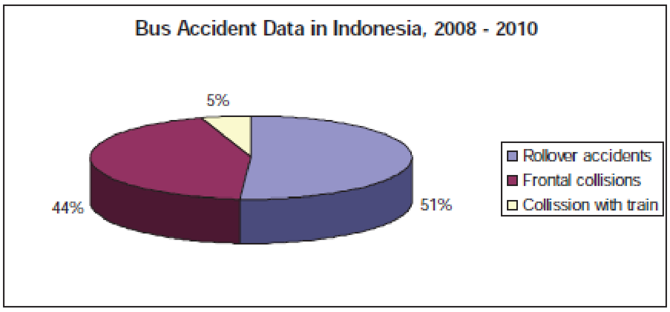

Fig. 1 Bus accident data in Indonesia

Karliński, M. Ptak [1] presented the modelling of a bus superstructure and strength analysis of bus structure and evaluates the requirements of Regulation ECE R66 using the finite element method, with consideration of nonlinearity of materials and geometry. D. Senthil Kumar [2] presented the study of bus rollover according to “Automotive Indian Standard Regulation No. 031” (AIS 031) / ECE R66 (Economic commission for Europe Regulation No. 66) conditions. The aim of this study was to investigate the impact on passenger residual space as per AIS 031 regulation. Dan Alexandru Micu and Daniel Mihail Iozsa [3] presented computer simulation of a bus rollover, on a complete vehicle and can be used as approval method. Rogov Petr Sergeevich [4] focused on study which contains the search for methods of verification of bus rollover finite element simulation which can replace a full-scale verification rollover test using single bus section. Kyoung-Tak Kang and Heoung-Jae Chun [5] presented design of a composite roll bar for the improvement of bus rollover crashworthiness. The objectives are like, to prepare FE model of bus for rollover test, obtain material properties like yield strength, young's modulus etc. using UTM. It is essential that the bus superstructure be stiff enough to protect the occupant survival space from any intrusion, while absorbing maximum crash energy. Performing experimental tensile test on material specimen using UTM. Performing bending test on component level in FEA and physical test to validate the material.

II. Finite Element Modeling

The main aim of finite element model of the bus is to capture the deformation and interaction of bus systems during rollover impact. FE modelling process involves CAD data, pre-processing, meshing, deck preparation, and processor (LS-DYNA). Also post-processor, displacement plot and energy plot. The residual space is the volume within the passenger compartment, which the bus structure must unharmed during and after rollover to protect the occupants or passengers. The residual space which is to be unharmed during rollover of bus is shown in Fig. 2. The meshed model of bus structure is also shown in Fig. 3.

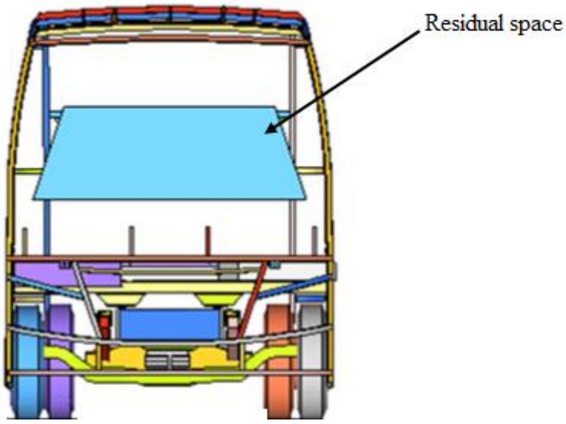

Fig.2 Residual Space (Survival Space)

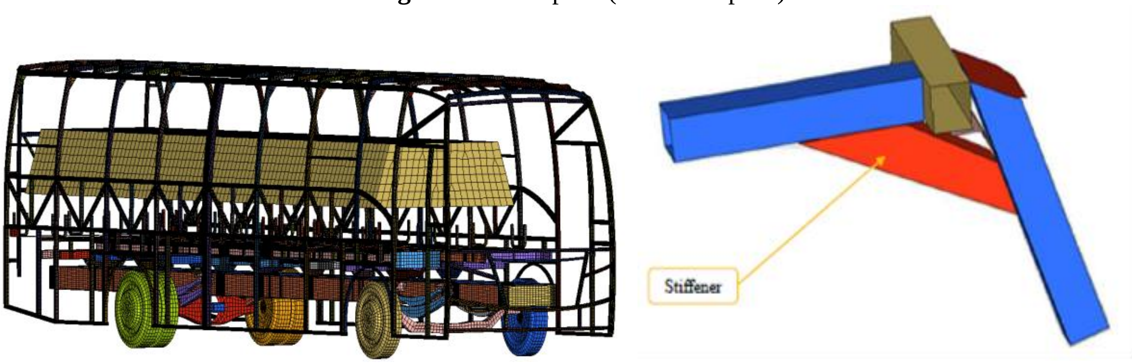

Fig. 3 Meshed model of bus structure with modified side pillars

III. Numerical Analysis

Numerical analysis of bus structure is used for finding whether the residual space intrude into structure or not. This contents imposing meshed model of bus superstructure into explicit solver LS-DYNA. Results of rollover test applied on superstructure is displacement plot and energy plot.Rollover analysis of bus using Ls-Dyna for initial bus model and redesigned bus model with addition of stiffeners can be done as, The initial velocity can be given as 2.98 m/s. Energy applied to the structure was $E = 57.71 * 10^6$ J. And it taken as initial boundary condition. From energy balance graph shown in Fig. 4, the kinetic energy decreases and is transformed into internal energy of whole bus structure with time, and the hourglass energy is considered as negligible. At the point of contact to ground surface of bus structure, the kinetic and internal energy line crosses to each other, such point on time consideration was recorded. To improve strength and stiffness requirements of bus structure and to avoid above problem, we need to add stiffeners as shown in fig 6. Stiffeners having dimensions of 50 x 50 x 2.5 mm with material as mild steel (M.S.).

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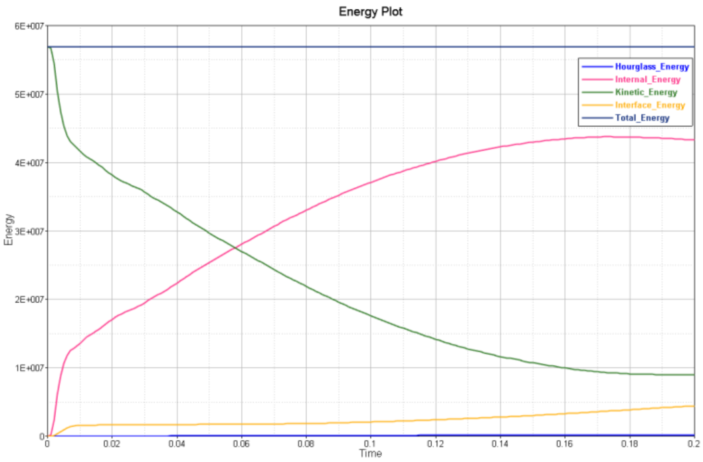

Fig. 4 Energy balance graph for redesigned bus model

Case 1: Initial bus model

From Fig. 4At the point of contact to ground surface of bus structure, the kinetic and internal energy line crosses to each other, such point on time consideration was recorded. The time was t = 0.075 sec. So, energy transformation rate from kinetic energy to internal energy affects the energy absorbed in the structure. Total time for complete energy transformation for base bus model was t = 0.2 – 0.075 = 0.129 sec.

Case 2: Redesigned bus model

The time was t = 0.0575 sec. So, energy transformation rate from kinetic energy to internal energy affects the energy absorbed in the structure. Total time for complete energy transformation for base bus model was t = 0.2 – 0.0575 = 0.1425 sec.

Table 1 FEA comparison of energy transfer for old bus and modified bus model

Time 't' to transfer energy (sec.)		***% Improvement***
Old Bus Model	***Stiffer (modified) Bus Model***	
0.129	0.1425	9.473

From Table 1, it was found that 9.47 % time increased to reach t = 0.2 sec after bus structure contacting to ground surface. Hence modified bus design with addition of stiffener having more elastic energy to slide on ground surface compared to old design and improved crashworthiness performance of bus structure.

IV. Experimental Investigation

1. Three point bending test on roll bar

Three-point bending test of the roll bar was carried out to find properties like maximum load carrying capacity and peak deformation for mild steel. Three-point bending test is the important criteria for strength of bus superstructure. The load- deflection curve was measured in laboratory.

2. Validation of three point bending test using FEA

The experimental test and its validation on roll bar used for stiffeners are shown in Fig. 5. Also load- deflection curve is plotted in Fig. 6 as below. Load–deflection curves for the experiment and simulation for 3 point bending on mild steel roll bar were compared, and it was found that there was a strong correlation between the experiment and simulation results.

V. Conclusion

From FEA, it conclude that, there is increase in energy transfer time for stiffer (new) bus model. The energy transfer time increase by 9.473 %. From experimental and the simulation result, it is concluded that, new designed roll-bar structure with addition of stiffener have more crash energy absorption capacity compared to old bus structure. So, improved the crashworthiness performance of bus superstructure.

Fig.5 Three point bending test- experimental and Ls-dyna simulation

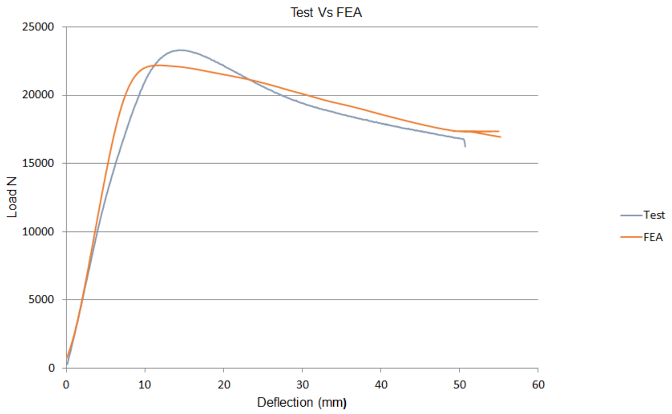

Fig. 6 Comparison of the test and LS-DYNA simulation on the 3 point bending

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