Optimal Design of Bus Frame StructureConsidering the Rollover Safety

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ABSTRACT

The transit bus is an important part of the public transportation, while in a bus rollover accident the deforming superstructure seriously threatens the lives of the passengers and the crew in the bus. Thus, bus rollover safety and how to design a bus superstructure so that obtaining a good stiffness of vehicle frame those are important works for bus manufacturers. Both Europe and the United States (US) have enforced the legislations for bus rollover protection: Regulation number 66 of the Economic Commission for Europe (ECE R66) and standard number 220 of the American Federal Motor Vehicle Safety Standards (FMVSS 220) in order to prevent catastrophic rollover accidents. Therefore, this dissertation discussed the legislation for bus rollover protection including both ECE R66 and FMVSS 220, a robust and efficient method for optimal strengthening and lightweight optimization. Satisfying the rollover requirements by buses is obligatory by law. However, the scope of those two regulations does overlap for some group of vehicles. Thus, this study firstly presents a physical meaning comparative analysis of the ECE R66 with the FMVSS 220. The LS-DYNA 971/MPP was used for numerical analysis. The analysis models were constructed by the eta/FEMB that is a preprocessing module integrated in the LS-DYNA 971 package. The validation was turned from experimental data of body knots extracted from the real vehicle. This investigation performed the comparative analysis following ECE R66 and FMVSS 220 assessments, then moved to demonstrate the distortion configuration of the vehicle superstructure through the absorbed energy and its distribution in the vehicle and the vehicle frame sections, as well as the violation of the passenger compartment under the rollover testing conditions of both ECE R66 and FMVSS 220. Great differences were found between the rollover strength of bus superstructures depending on which regulations are followed. The results also demonstrate that the passenger compartment and residual space are more violated and more dangerous under the lateral rollover testing condition of the ECE R66 than the other. Avoiding the intrusion into the survival space, the bus fame stiffness is needed to be considered. However, strengthening the bus superstructure is usually causes the raising of vehicle weight. This study secondly presents an efficient and robust analysis methodology to design the bus superstructure for a reduction in occupant injuries from rollover accidents while the weight of the strengthened bus was maintained at the same level. Where, the absorbed energy of the bus frame and its components during rollover were investigated by LS-DYNA. The highest energy absorption region, which is side wall section of the bus frame, was found and focused on for the investigation and redistribution of the energy absorption ability of the side wall component. The thickness parameters obtained from the redistribution of the energy absorption ability were used in the analysis to optimize the design. On that basis, the study presents both procedures for bus rollover crashworthiness design related to vehicle weight. One is an optimization via based on regression analysis using MS-Excel, other is an automated optimization via analysis based on the technique combined LS-DYNA and LS-OPT. Both procedures show the significant improvement in the deformation of bus frame versus the vehicle ' s survivor space while maintaining the bus weight at the existing level. Strengthening the bus frame to maintain survivor space and reduce occupant injury is a necessary following the issue of ECE R66. Whilst lightweight structures in bus body design has also been highlighted. Therefore, this study finally presents a lightweight optimisation considering the bus rollover crashworthiness design. In this part of the study, besides the analysis of the side wall section, the roof section of bus frame was also analyzed based on energy absorption ability in order to specify the design variables. With the aim of improving both the deformation of bus frame versus the vehicle ' s survivor space and the body skeleton density of vehicle structure, optimisation was performed by LS-OPT with the successive respond surface method (SRSM), where LS-DYNA was used as the FE solver. An optimal vehicle model was obtained with lightweight structure and crashworthiness following ECE R66. Above findings could be used for the automobile manufacturers in a new design of bus superstructure, incorporating the rollover safety legislation and lightweight.

Keywords : Bus Rollover、Superstructure、ECE R66、FMVSS 220、Energy Absorption、LS-DYNA、Optimization
、Lightweight、LS-OPT

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