Bus Rollover Protection Analysis with LS-DYNA as an approval method according to American and Europe Standards

Abstract: The bus rollover is one of the most awful vehicle accidents. When a bus rollover occurs, because of the capacity of the passengers, the casualties are severe. The satisfying of rollover requirements for buses and coaches are obligatory. For this reason, this paper presents a physical meaning comparative analysis of the regulation No.66 of Economic Commission for Europe (ECE R66) and the standard No.220 of Federal Motor Vehicle Safety Standard in American (FMVSS 220) by using finite element solver LS-DYNA. This investigation firstly provided a comparative analysis of the absorbed energy ability of the superstructure and its main regions and secondly gave out an evaluation of the displacement level of window and door upper bars which are the main components that strongly obstruct the opening of emergency exits in FMVSS 220 test and may violate survivor space in ECE R66 test. These results show a difference between ECE R66 and FMVSS 220 and provide a means in evaluating bus superstructure strength.

Keywords: Rollover, Superstructure, ECE R66, FMVSS 220, LS-DYNA

1. INTRODUCTION

Avoid verbosity and redundancy!

There are a lot of heart-breaking bus accidents. As a result, according to the worldwide rollover accident statistics, only from 1973 until now, there are more than 570 bus rollover accidents [1, 2]. Although the bus rollover accidents are less than other kinds, it is so severe. For this reason, in U.S.A, Europe and some countries, the bus rollover safety has already been enforced for buses and coaches approval to reduce occupant injury. On Jan 4th, 1977 the Department of Transportation...
United States of America had enforced the FMVSS 220 standard for the school bus rollover protection which included transit buses and vans having the lengthless than 35 feet [3, 4]. On Jan 1, 1987, Economic Commission for Europe had enforced Regulation No.66 for Bus Strength of Superstructure in order to provide protection to bus and coach occupants during rollover accidents type through maintenance of a survival space [5, 6].

Besides, other countries have regulations or standards for this accident type too. For example, the SANS 1563 regulation for the strength of large passenger vehicle superstructures (rollover protection) in South Africa, and ADR 59/00 for the Omnibus rollover strength in Australia which are the modified versions of ECE R66 [7]. All of them are obligatory in each country. However, the methods in use and the enforcing power of these regulations are different. Furthermore, the Bus Manufacturing Factories want to bring their products onto the European or USA or both of the markets. While the Bus rollover safety in Europe is evaluated by ECE R66 and by FMVSS 220 in USA for school bus. Therefore this paper is investigating the comparative analysis between ECE R66 and FMVSS 220, two main regulations for bus rollover safety based on computer simulation.

In recent years, Automotive industries are concentrating more on vehicle rollover. There were many researchers to study the structure strength of buses and the injury analysis of passengers in accordance with tests of the ECE R66 [5, 6]. Brow (1990) [8] tried to use the CRASH-D program to be a tool for design and type approval of coach structures for rollover. Examples are given of CRASH-D analyses on a coach bay structure and on various structure joints and sections. The program has been validated against full-size physical rollover tests. Keeman et al. (1990) [9] discussed that the effect of "finite stiffness hinges" on the energy absorbing capacity of a bus body structure subject to the type of approval procedure (according to the ECE R66) on rollover safety. Modeling aspect of the same effect in the finite element analysis of the collapsing ring have also been presented and illustrated by comparative tests on components and portal frames. Toni et al. (1997) [10] showed that they have developed a simulation procedure using finite element analysis.
for studying the structural resistance comply with ECE R66 without actually performing a rollover test. Aleksandar et al. (1997) [11] pointed out to the improvement of vehicle stability and crashworthiness to reduce rollover and to provide increased occupant protection in the event of rollover, requires that the effects of design parameters on vehicle rollover propensity are thoroughly understood. They showed that the roof configuration can be modified by replacing the longitudinal bars with diagonal bars across the entire length of the structure. The sensitivity design studies have identified this as a viable approach resulting in lower mass of the bus frame (by up to 3%) and in a reduction of the height of the center of gravity (by up to 2%), thus producing a better rollover of the bus. Matyas (1998) [12] gave an analysis about rollover process of a bus in case of a standard accident simulation. International regulation requires certain strength and energy absorbing capacity of the superstructure to ensure survival space for passengers. The kinetic energy of a rolling bus is transformed into deformation work and involving the energy losses too, an energy balance can be set up and studied. Sándor (1998) [13] showed that the European Committee of Economy has accepted and issued a new regulation related to the bus superstructure's strength in 1986. The previous methods and all the four test methods, accepted in ECE R66, are discussed technically and critically in this paper. And also pointed out that the recently used combined Hungarian method based on quasi-static tests of bus-frames and simplified computer simulation of rollover proves is presented too. Jamie (2000) [14] reported that the ECE Regulation 66 is a regulation for all newly registered coaches to be type-approved for rollover crashworthiness. Additionally to the approval type, a computer model was developed to predict the full-scale rollover test. This model comprised a detail finite element mesh and analyzed dynamically using LS-DYNA software. It was approved by the Vehicle Certification Agency in UK, so that it could be used to gain future extension to the ECE R66 approval type of the Bova coach, without the need for repeat rollover test. Matyas (2001) [15] pointed that the ECE R66 did not say too much about the problems and details of body section rollover test. This paper collected and discussed these problems and tried to find solutions. And showed that it is a big problem to decide the standard of body sections and evaluate the test results.
Belingardi et al. (2003) [16] studied the effect of a rollover accident over the structure and the passengers. For what concern the rollover of bus, in Europe the regulation for safety approval is ECE R66. The effect of occupants mass over the superstructure and the injury risk for passengers in a rollover accident was evaluated considering different configurations. The program being chosen to carry out the simulation is MADYMO, the MB-FE software developed by TNO. The mass increment due to presence of passengers effects significantly the deformation of the superstructure and the absence of any prescription of restrain systems does not permit to protect the passengers against very serious or fatal injuries. Castejon et al. (2004) [17] showed a simulation technical for the rollover test. This technical is based on Geneva regulation number 66. Moreover, a prototype of the composite bus in the Hispano Carrocera S.A. Company has been developed and manufactured, in order to be tested under several load cases, enclosing dynamic and static measurement with strain gages at representative points. Belingardi et al. 2005 [18] investigated the influence of the seat and the restraint system on bus body structure strength and effects of injury on passengers themselves by using Bay section multibody (MB) and EUROSID-1 dummy model. And they also developed the MB seat model to use. Lin et al. (2006) [19] built CAE model and used the sensitivity and optimization analysis methodology to study the relationship between the lowest shear mode and the weight of the bus to find out the optimized parameters for building a new model meeting the ECE R66. Although many studies have been done on bus structure strength, almost of them are flowing or based on ECE R66 to carrying out their researches. The ECE R66 is a main regulation about the strength of superstructure that prescribes a test to be chosen between its different kinds. Another regulation about the structure strength is FMVSS 220 [3] that describes the school bus rollover protection. However, the comparative analysis between ECE R66 and FMVSS 220 is still limited.

Until now, the capacity of computer and FE software are confirmed in predictive analysis and computing assistances of Bus structure [8, 10, 14, 16-21]. That is also new point in ECE R66 version 2006 in which the computer simulation with full scale model is official using as an assessing method for the bus rollover protection requirements [6]. This paper used LS-DYNA code.