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Original Research Article

# Strength analysis of bus superstructure according to Regulation No. 66 of UN/ECE

*J. Karliński, M. Ptak *, P. Działak, E. Rusiński*

*Wroclaw University of Technology, Faculty of Mechanical Engineering, Institute of Machines Design and Operation, Computer-Aided Design Division, Łukasiewicza 7/9, 50-371 Wroclaw, Poland*

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ABSTRACT

The article presents the modelling of a bus superstructure and its strength analysis and evaluates the requirements of Regulation No. 66 using the finite element method, with consideration of nonlinearity of materials and geometry. The analysis includes a strength test simulation in the form of a rollover test, which was performed in accordance with the requirements specified in Regulation No. 66 of UN/ECE and annex no. 3 of Regulation 66 of UN/ECE. The article presents the results of the dynamic analysis which uses the finite element method.



## 1. Introduction

Since 2004 it has been mandatory to update and amend the law of the new integrated European Union (EU) members to satisfy the requirements included in EU Directives. These changes also pertain to means of transport, including buses. The requirements for those vehicles are established in Directive No. 2001/85/EC of the European Parliament and of the Council. It relates to special provisions for vehicles used for the carriage of passengers comprising more than eight seats in addition to the driver's seat and amends Directives 70/156/EEC and 97/27/EC. It is also one of the separate Directives related to the EC type-approval as defined by Directive 70/156/EEC. It introduces the necessity to take into consideration the technical requirements adopted by the Economic Commission for Europe of the UN (UN/ECE) in its Regulations:

- No. 36 – 'Uniform provisions concerning the approval of large passenger vehicles with regard to their general construction',
- No. 52 – 'Uniform provisions concerning the construction of small capacity public service vehicles',
- No. 66 – 'Uniform provisions concerning the approval of large passenger vehicles with regard to the strength of their superstructure',
- No. 107 – 'Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction',

attached to the 1958 Agreement Concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts.

The purpose of Directive No. 2001/85/EC is to guarantee the safety of passengers and to avoid trade barriers within the

* *Corresponding author*. Tel.: +48 71 320 29 46; fax: +48 71 320 31 23.
E-mail address: mariusz.ptak@pwr.wroc.pl (M. Ptak).

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**Fig. 1 – Infringed coach superstructure.**

**Fig. 2 – Significant deformation of side walls.**

**Fig. 3 – Damaged superstructure of double-decker bus.**

Community resulting from differences in technical prescriptions of buses. The Directive sets out requirements for different bus construction elements, including the superstructure. In order to obtain the EC type-approval, the vehicles must satisfy requirements concerning the strength of the superstructure. The Directive defines the methods, conditions and evaluation criteria for strength tests, which are based on the guidelines in Regulation No. 66 of UN/ECE. Therefore it is agreed that all vehicles which satisfy the requirements of the Regulation automatically conform to the provisions of the Directive [1].

Because of the number of passengers on board, road accidents involving buses are usually very tragic. The bus structure has a direct influence on the protection of life and health of the transported passengers and guarantees the life space which is necessary in the event of an accident. The rollover of a bus is exceptionally dangerous as it causes significant deformation of the roof and side walls. A bus rollover most frequently occurs when the vehicle leaves the road and goes down a slope or runs over an obstacle on the side of the road, e.g. the pavement. Buses rarely roll over due to centrifugal acceleration resulting from travelling a curve. Nevertheless, in every case of a rollover the consequences are tragic. Figs. 1–3 show real-life photographs illustrating rollover accidents of the coaches. The presented examples illustrate the importance of proper studies on the real strength of structures during rollover. In France, for instance, since 2000 there have been 2 to 3 serious coach accidents per year, with most of these accidents happening on expressways, whereas prior to 2000 there was less than one accident per year (Table 1).

## 2. Analysis of bus superstructure

Pursuant to Regulation No. 66 of the Economic Commission for Europe of the United Nations (UN/ECE) strength tests of the superstructure are applied to all single deck rigid or articulated vehicles designed and constructed for transportation of over 22 seated or standing passengers, excluding the driver and crew. The Regulation defines the methods of testing strength and specifies the rollover test as the basic approval method and equivalent approval methods:

- annex 6: Rollover test using body sections as an equivalent approval method.
- annex 7: Quasi-static loading test of body sections as an equivalent approval method.
  - Appendix 1 – Determination of the vertical movement of the centre of gravity during rollover.
- annex 8: Quasi-static calculation based on testing of components as an equivalent approval method.
  - Appendix 1 – Characteristics of plastic hinges.
- annex 9: Computer simulation of rollover test on complete vehicle as an equivalent approval method.

The rollover test defined in annex 5 is the basic method and consists in a test on a complete, full-scale vehicle to confirm the required strength of the superstructure. The superstructure of the vehicle should have the sufficient strength to ensure that the residual space during and after the rollover test on complete vehicle is unharmed. This means:

- no part of the vehicle which is outside the residual space at the start of the test should intrude into the residual space during the test. Any structural parts, which are originally in the residual space (e.g. vertical handholds, partitions,