5th International Conference
″Computational Mechanics and Virtual Engineering ″
COMEC 2013
24- 25 October 2013, Braşov, Romania

A ROLLOVER TEST OF BUS BODY SECTIONS USING ANSYS

D.A. Micu, [1], M.D. Iozsa[2], Gh. Frățilă[3]
[1] University Politehnica of Bucharest, ROMANIA, dan.alexandru.micu85@gmail.com
[2] University Politehnica of Bucharest, ROMANIA, daniel_iozsa@yahoo.com
[3] University Politehnica of Bucharest, ROMANIA, ghe_fratila@yahoo.com

Abstract: *The homologation of buses depends on its behavior during the rollover tests. This paper presents a computer simulation of rollover test on a body section of a structure constructed in order to be used for new bus models. Pendulum test on a bodywork section from Directive 2001/85/EC is used as a test method for rollover test. The geometrical model and the material proprieties are designed through the Ansys 13 software, using a real structure as a reference. The pendulum and the residual space are the other two designed parts for the simulation process, an interconnection being used just between the structure part and the pendulum part. The pendulum velocity is calculated using the equivalent mass of the body section, including the loads of elements which are not part of the structure. The rollover behaviour results should be improved. The next steps will be to verify which properties should be changed to make this improvement.*
Keywords: *bus, rollover, Ansys, tests, pendulum*

1. INTRODUCTION

Accident statistics show that bus rollover accidents occur with relative low frequency, taking into account all kinds of bus accidents. Nevertheless the risk of mortality in the case of rollover is five times greater compared with any other possible bus accident typology [1].
The automotive regulations establish the rules that have to be respected by the bus body designers in order to get the homologations. The vehicle framework should absorb the impact caused by vehicle rollover so that the kinetic energy of the impact is converted into structure deformation work [2]. A very stiff superstructure is needed to keep an intact survival space after deformation, while the respect of the limits on the biomechanical parameters needs a structure with large energy absorption capability [3]. Computer simulation of a rollover test on a complete vehicle is an approval method that can be used. It allows manufacturers to test design and safety features virtually in the crash scenario until they obtain the safest and optimum design, thus saving time and money in developing expensive costly prototypes [4]. For the automotive manufactures the question is which is the best structural geometry or material that should be used in order to satisfy both stiffness and energy absorption capability.
In [2], simulation tests of the strength of elementary tubular profiles when hitting non-deformable ground surface have revealed that, from the point of view of resistance to impacts and energy absorption, the rectangular cross-sections of bus bodies may turn out to be dangerous for bus occupants, while the bus body frameworks with alternative symmetric circular shapes would provide better safety for bus passengers.
The formation process of plastic hinges along the pillars is fundamental for an adequate energy absorption, was concluded in [3], in which an optimization program based on the exploration of the response surfaces with fractional factorial plans that allows to obtain a design solution satisfying both deformation and energy absorption requests.
One of conclusions from [1] was that from the point of view of safety it will be necessary to model the vehicle with great detail so simplified finite element models should only be used at preliminary design phases.
The pendulum method according to the EU Directive No. 2001/85/EC of 20 Novembre 2001, entitled “Strength of superstructure” is presented in the next sections. This is the method used to analyze, through computer simulation, the rollover behavior of a body section of a structure constructed in order to be used for new bus models. The geometrical model and the material proprieties are designed through the Ansys 13 software, using a real structure as a reference. The pendulum velocity is calculated using the equivalent mass of the body section, including the loads of elements which are not part of the structure.

2. MODEL DEVELOPMENT

2.1. Pendulum Method

EU directive 2007/46, establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, made two references for strength of superstructure to Directive 2001/85/EC and to UNECE Regulation Number 66. The pendulum method is not anymore a method specified in UNECE Regulation Number 66. It was presented in the old version of the Regulation, but it is still specified in Directive 2001/85/EC.

In pendulum test on a bodywork section, the energy to be transmitted to a particular bodywork section shall be the sum of the energies declared by the manufacturer to be allocated to each of the cross-sectional rings included in that particular bodywork section.

The most important test conditions are:

- a sufficient number of tests shall be carried out for the technical service conducting the test to be satisfied that no displaced part of the vehicle intrudes into the residual space;
- the side of the bodywork section to be impacted shall be at the discretion of the manufacturer;
- high speed photography, deformable templates or other suitable means shall be used;
- the bodywork section to be tested shall be firmly and securely attached to the mounting frame through the cross-bearers or parts which replace these in such a way that no significant energy is absorbed in the support frame and its attachments during the impact;
- the pendulum shall be released from such a height that it strikes the bodywork section at a speed of between 3 and 8 m/s.

The high of the centre of gravity is established by the designer and the fall of the centre of gravity (h) is determined by graphical methods. The total energy (E*) may be taken to be given by the formula:

$$E^* = 0{,}75 \cdot M \cdot g \cdot h \quad \text{(Nm)} \tag{1}$$

The unladen mass of the vehicle (M) is used to determine the distribution of mass on the tested structure section. The angle between the central longitudinal vertical plane of the bodywork section and the horizontal ground is determined as it is presented in Figure 1.

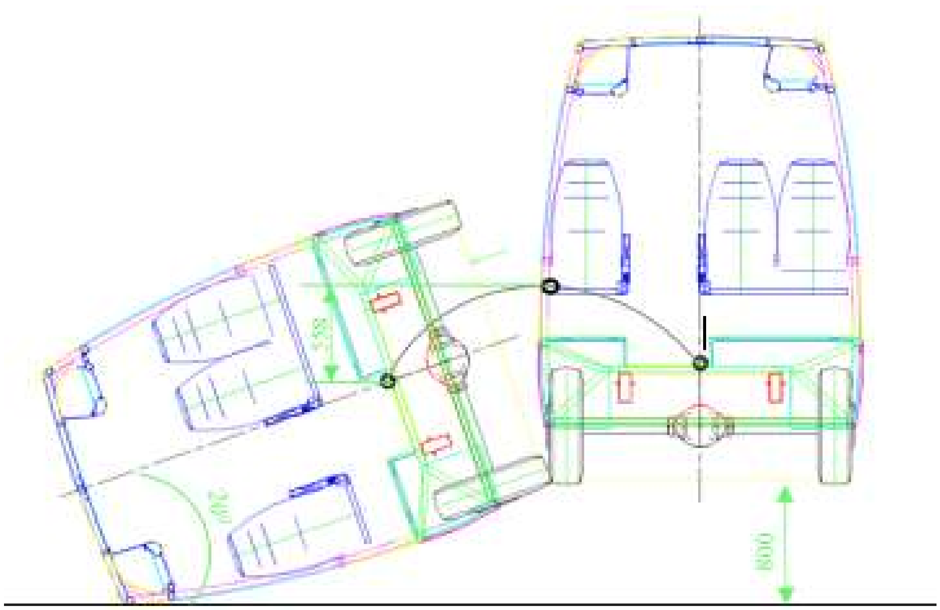


Figure 1: The determination of the fall of the centre of gravity

Using the energy conservation law, by equating the kinetic energy of the block, at the moment of the impact, with the total energy impact, the speed value that needs to be used for the block can be identified. The mass of the pendulum, the value of the initial speed of the pendulum and the absorbed energy of the structure are determined.

2.2. The model

The analyze started from a real structure realized by a company in order to use it for new versions of buses. It is prepared to be tested it with „Roll-over test on a bodywork section” method. A frontal view of the bodywork is presented in Figure 2.

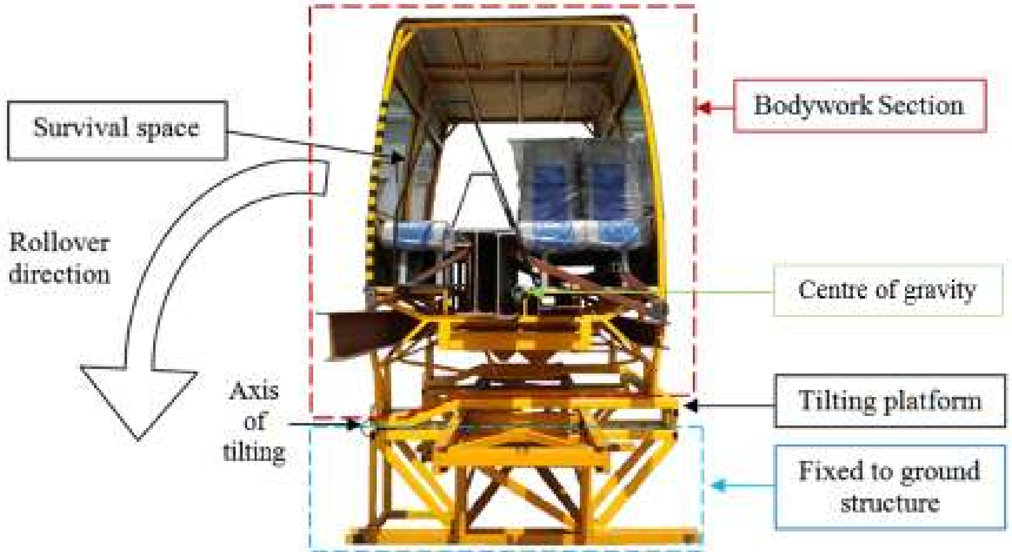


Figure 2: The real structure of the bodywork section model

The bodywork section represents a section of the unladen vehicle. Some additional beams are welded to the structure to simulate the mass of the completed section and to establish the right centre of gravity. The survival space is defined by two shapes mounted in the front and in the back part of the structure. The bodywork section is installed on the upper part of a tilting platform, which is rotated around the axis of tilting. The fixed to ground structure has a height of 800 mm, like the one specified in Directive 2001/85/EC.

This article presents the verification of strength of the superstructure by calculation, considered it as a preliminary design phase. In order to analyze the structure behaviour during it is subjected to the rollover test, ANSYS was used - a computer software specialized in the analysis of structures using the finite element method.

Specific stages are required to make an evaluation: designing the geometrical model, meshing, processing the calculations and results interpretation. The segment presented in Figure 2 was designed. The real model as well as the finite element model contain the space of survival. In this way it will be easier to observe whether the structure enters this space during the rollover process.

The structure is made of rolled bars of a rectangular, square or L-shaped profile. The entire geometrical model was composed of surfaces. The structure is constrained in the bottom part through some fixed support applied on faces of longitudinal and transversal elements. Figure 3 shows the geometrical model developed using ANSYS software.

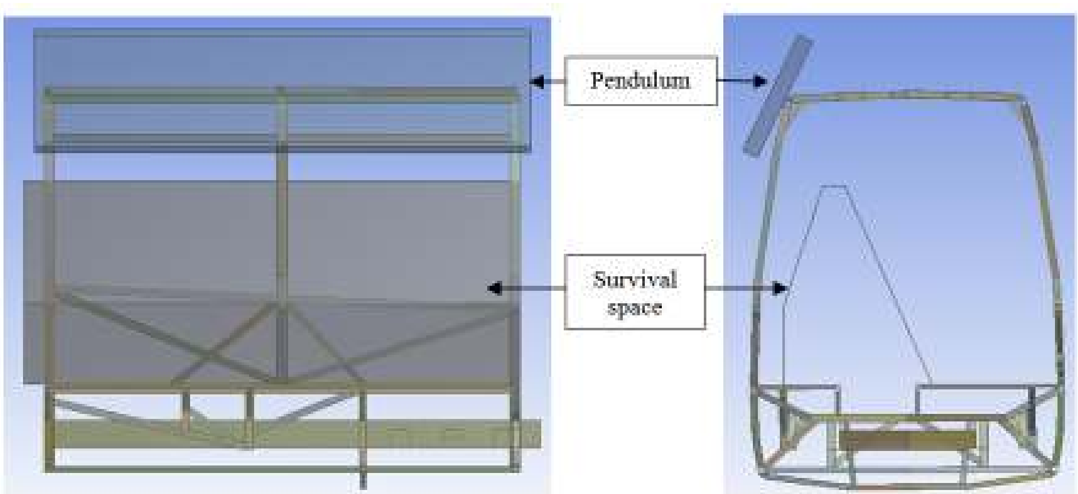
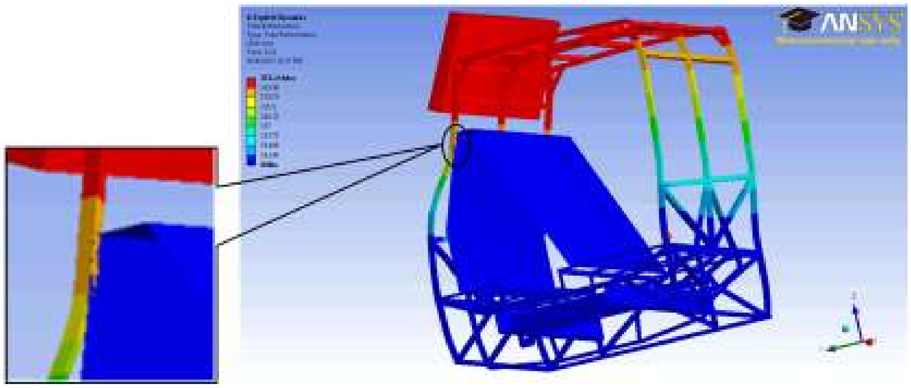


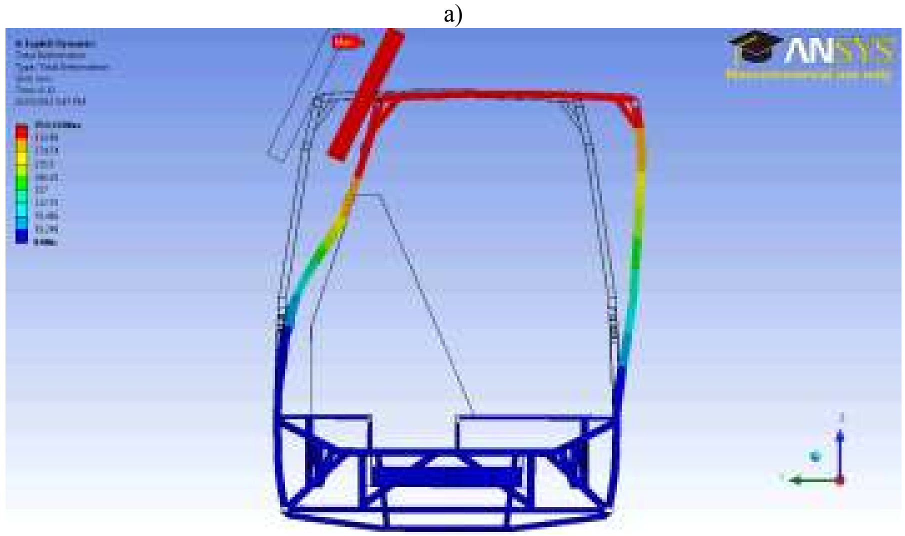
Figure 3: The finite elements section model

2.3. Results

The rollover behaviour using the energy resulted from Directive 2001/85 was studied in the first analyse. The computation has stopped before the pendulum's velocity get to zero. Even so, the structure has intruded into the survival space, as it can be noticed in Figure 4.



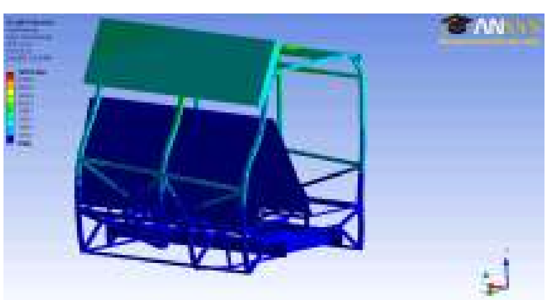
a)

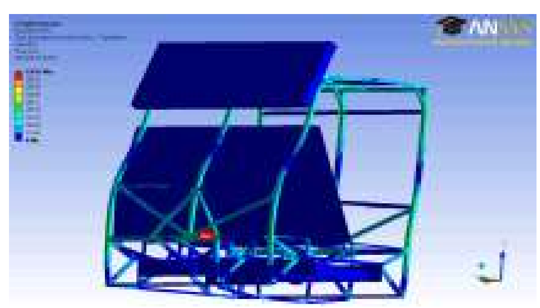


b)

Figure 4: The deformations of the finite elements section model

The velocity values of the structure and of the pendulum are presented in Figure 5.a). The structure presents some bigger values due to the vibrations, but the pendulum's velocity decreased. The stress results are smaller than the material limit and it can be seen in Figure 5.b).





a) b)

Figure 5: The velocities and the stress of the finite elements section model

What's happening when a part of the structure elements are missing was also studied. Four from six corner elements used to increase the structure strength were deleted, and the test was repeated. It was noticed that the cross-sectional ring that still have the corner element was deformed more than the others. This difference is presented in Figure 6, where it can be noticed that the maximum displacement is present on a bigger surface of the pole from the cross-sectional ring with the corner element.

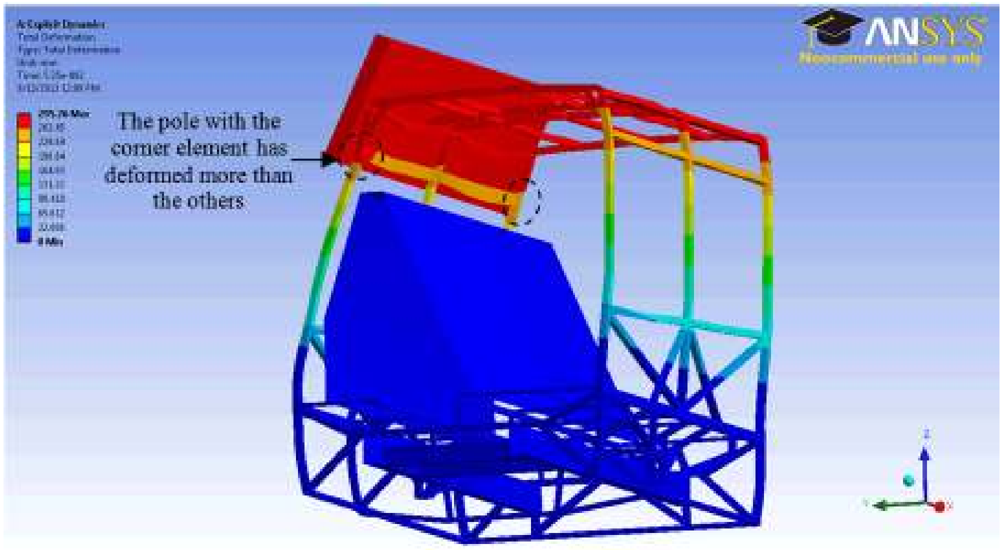


Figure 6: The influence of using an element in one corner of the cross-sectional rings

Another study is referring at a bigger mass of the structure to be considered during the rollover test. This is the mass used in the case the vehicle is fitted with occupant restraints, when Regulation 66 mentions the using of total effective vehicle mass. Using the equivalent energy, the resulted velocity for pendulum was almost doubled.

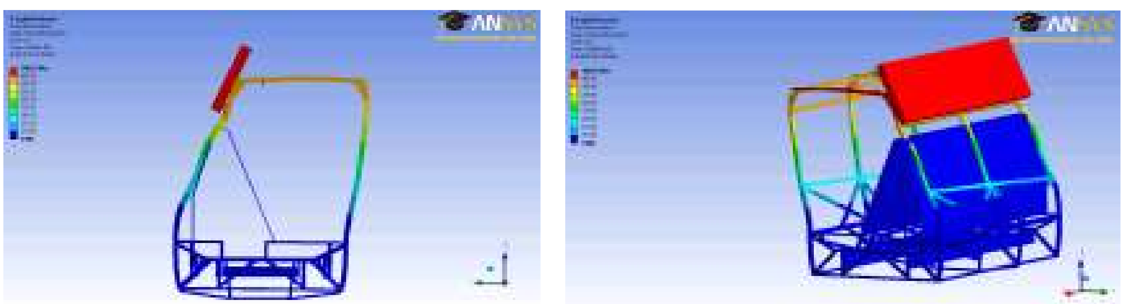
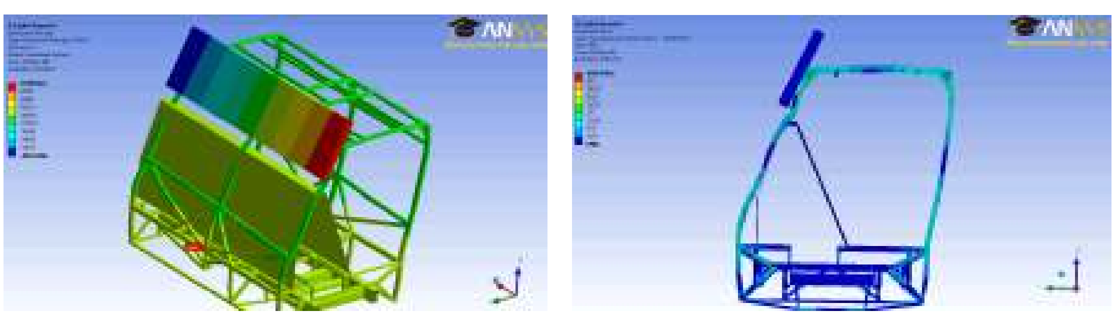


Figure 7: Deformations of the structure when it was considered a bigger mass

In this case the velocity of the pendulum has got to zero as it can be noticed in Figure 8.a). This process happened very fast, the pendulum being stopped in the lost few steps of processing, decreasing from almost half of the maximum speed of the pendulum. The stress values were also under the material limits (Figure 8.b)), except one point generated through the computer modelling.



a) b)

Figure 8: Velocity (a) and stress (b) resulted when it was considered a bigger mass

2.4. Discussion

The model studied in this article doesn't comply with all the specifications and requirements of Directive 2001/85/EC. In all cases the structure has intruded into the survival space, but the energy considered for this computations corresponds to the real model mass of the structure with the additional mass added. This additional mass is bigger than the one specified in the Directive.
The corner elements used for increasing the strength of the structure can lead to a bigger deformation of the pole of the cross-sectional ring where it is mounted.
The velocity of pendulum decreases very fast in the last deformation steps.

3. CONCLUSION

The verification of strength of a real structure by calculation using the pendulum method presented in Directive 2001/85 EC was studied in this paper. The model was designed and tested, using Ansys 13.0, for a real structure realized by a company in order to use it for new versions of buses. The model studied in this article doesn't comply with all the specifications and requirements of Directive 2001/85/EC. In all cases the structure has intruded into the survival space. The corner elements used for increasing the strength of the structure can lead to a bigger deformation of the pole of the cross-sectional ring where it is mounted. The velocity of pendulum decreases very fast in the last deformation steps. The next steps are to test some modified geometry parts and/or material proprieties, in order to find a better solution.

4. ACKNOWLEDGMENTS

Dan Alexandru Micu gratefully acknowledges the PhD funding from the Sectoral Operational Programme Human Resources Development 2007 - 2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreement POSDRU/107/1.5/S/76909.

REFERENCES

[1] Valladares D., Miralbes R. ,Castejon L., Development of a Numerical Technique for Bus Rollover Test Simulation by the F.E.M. , Proceedings of the World Congress on Engineering 2010, London, U.K., June 30 - July 2, 2010, Vol II;
[2] MARIAŃSKI M., SZOSLAND A., Research on the Strength of Standard Bus Bodies at Rollover on the Side, Technical University of Lodz, 2011;
[3] Belingardi G., Gastaldin D., Martella P., Peroni L., Multibody Analysis Of M3 Bus Rollover: Structural Behaviour And Passenger Injury Risk, Dipartimento di Meccanica, Politecnico di Torino, 2002;
[4] Micu D.A., Iozsa M.D., Analysis of the Rollover Behaviour of the Bus Bodies, Analele Universității „Eftimie Murgu", Reșița, 2011;
[5] Directive 2001/85/EC;
[6] Regulation 66-UNECE.