The 3rd International Conference on "Computational Mechanics and Virtual Engineering"
COMEC 2009
29 – 30 OCTOBER 2009, Brasov, Romania

ANALYTICAL PENDULUM METHOD USED TO PREDICT THE ROLLOVER BEHAVIOR OF A BODY STRUCTURE

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Abstract: *The deformation of the body structure during an accident can be predicted by experimental or analytical studies of the behaviour of the structure under the impact loads (frontal, lateral and roll-over impact).*
The rollover or crash test must be performed for any kind of motor vehicles. Many European regulations allow testing the impact or the rollover behaviour of the structure using the pendulum method.
The paper will present some results concerning the use of the analytical pendulum method in order to study the rollover behavior of a truck cab and of a bus structure.
Keywords: *rollover, truck, bus, pendulum, FEM*

1. INTRODUCTION

A structure which will offer a good protection in traffic accidents must to be almost non deformable under the action of accidents exceptional loads. In order to make more safety cars is very important to predict the impact behaviour of the body structure. Standardized testing for passive safety is often computer simulated but, legally, some experimental testing is demanded.
The FE method allows making deformable models of the body structure, models very useful to perform strength calculations and to study its static and dynamic behaviour. In the strength calculation of the structure under the exploitation loads is possible to use linear models for the material because the effective stresses must be under the allowable stresses. For good results in the dynamic analysis of a crash process is important to consider non-linear materials for the body structure, because the plastic deformation takes place through large displacements.
Many European regulations allow testing the impact or the rollover behaviour of the structure using the pendulum method. So, accidents like the front impact on the upper corner of the cab or the bus rollover can be simulated with a pendulum which hit the structure.
This paper presents a simulation using FE method, of the front impact on the upper corner of the cab of a truck and the rollover of a bus superstructure

2. THE FINITE ELEMENTS MODEL

The finite elements models are composed by the vehicle structure and a pendulum of M mass which will be lifted at H height (Figure 1). The energy of the cylinder when it will hit the cab is E=MgH (g is the gravity acceleration).
The cylinder which will hit the cab has the proper dimensions to obtain the wanted volume and the wanted mass M depended of the cylinder material density.
The deviation angle and the length of the pendulum are determining the height H of the cylinder position in order to obtain the wanted potential energy.

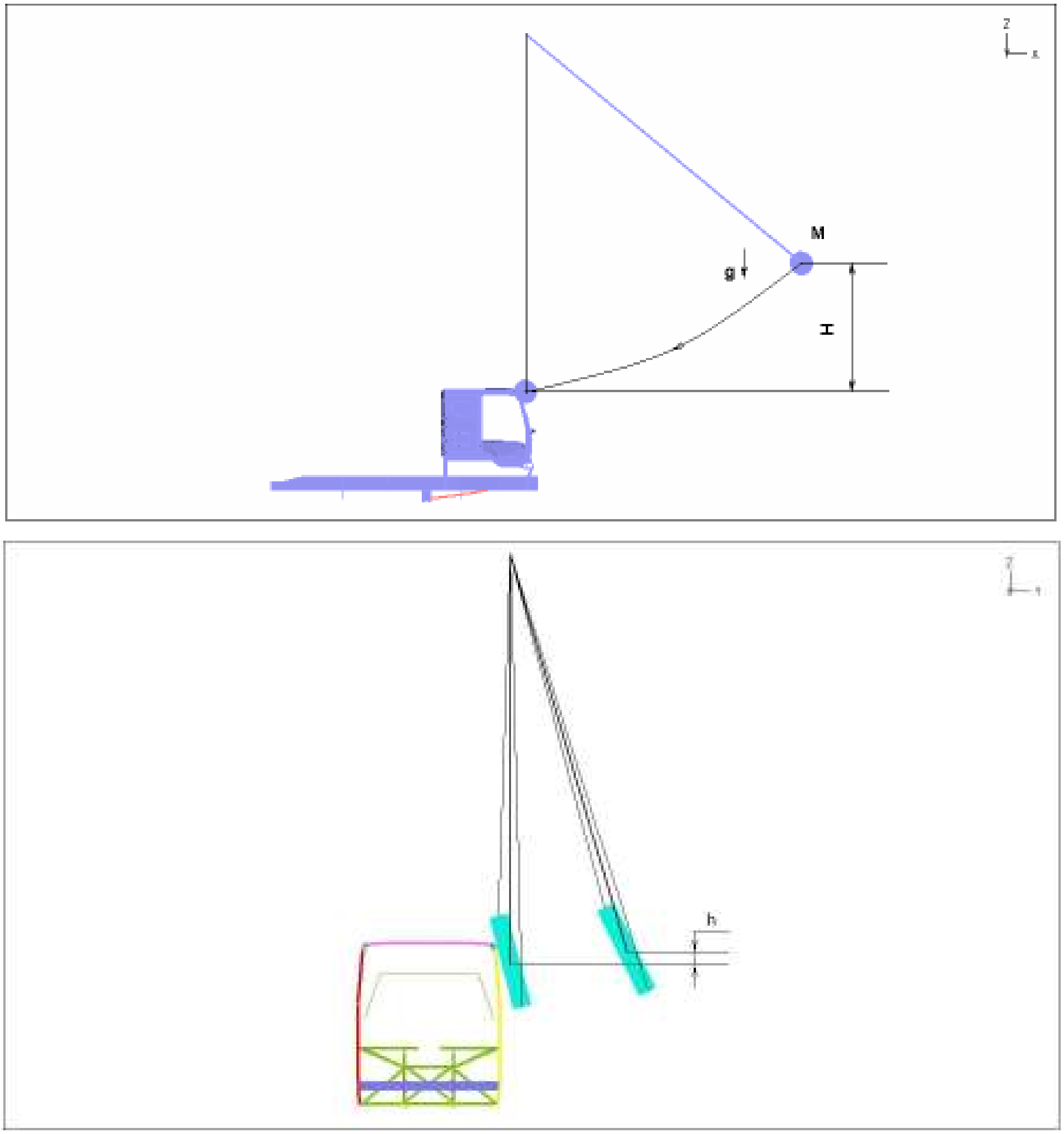

Figure 1: The pendulum model

The geometric models are developed starting from some real truck or bus structure.
The truck model (Figure 2) is composed by two parts (the chassis frame and the cab) connected by a mounting system with springs and dampers. It was used a cylindrical pendulum.
The bus model (Figure 3) is composed by the superstructure of the bus. It was used a rectangular pendulum.

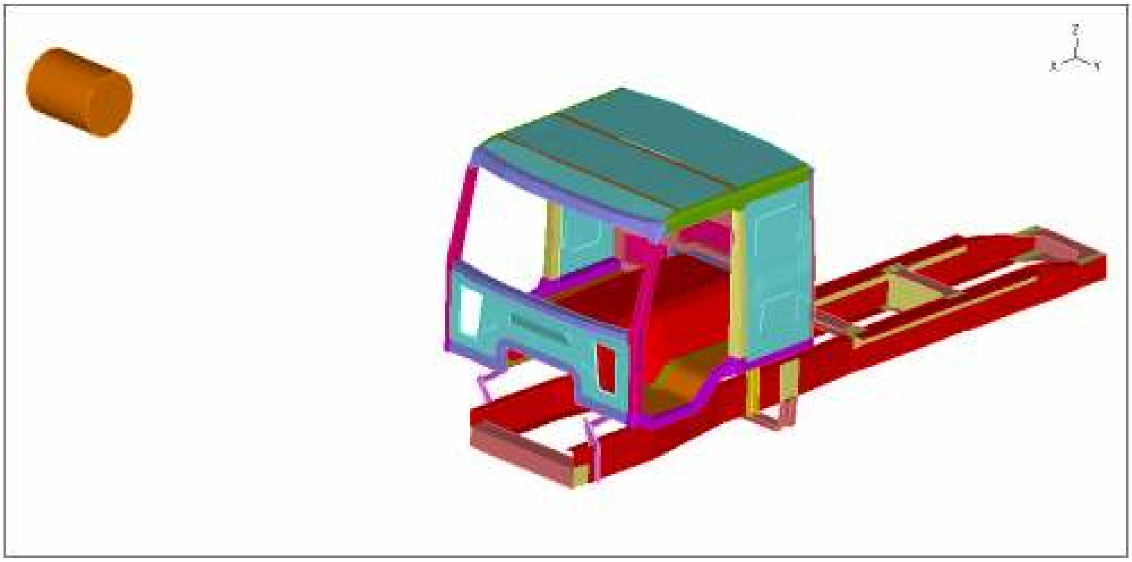

Figure 2: The geometric model of the truck

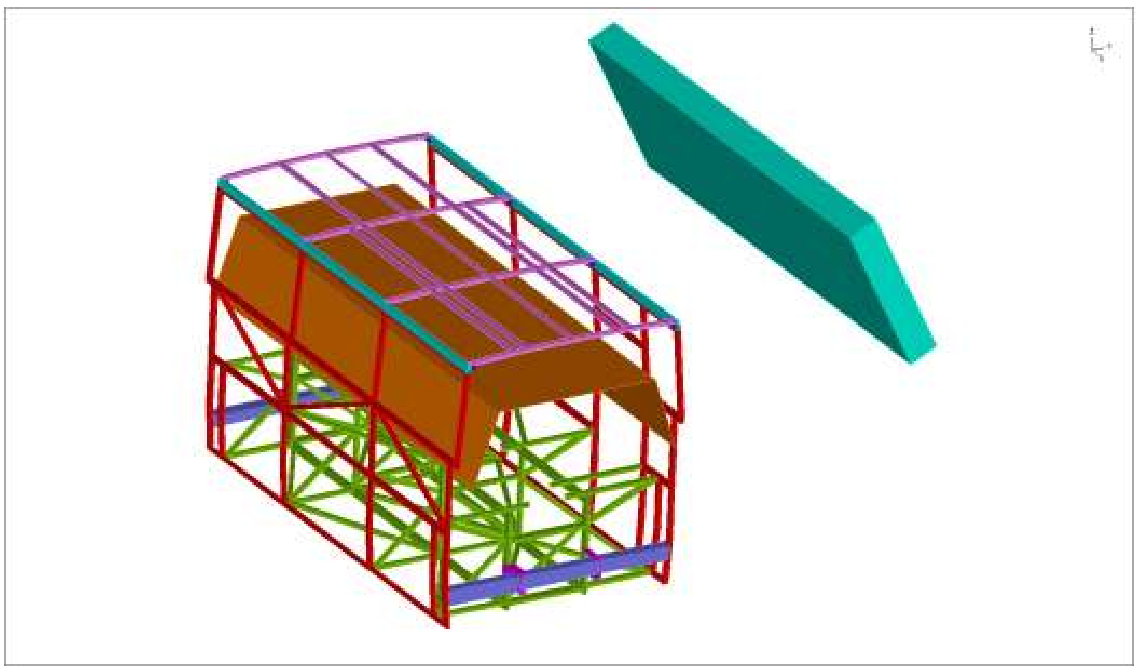

Figure 3: The geometric model of the bus

The structure of the body was meshed with shell elements. In order to simulate the articulations of the mounting system of the cab were used constraints equations. The pendulum was meshed with 3D-Solid elements and it was connected with the centre of the pendulum using rigid links.
The masses of the auxiliary components of the body were considered like mass elements positioned on the body model.
Along a dynamic analysis of an impact process, the effective stresses in the structure could be greater then the yield stress and in some areas, even then the ultimate tensile and the strain could be larger. These reasons make necessary to use nonlinear models for the structure material. The main characteristics of the bilinear material model used are: Young's modulus, Poisson's ratio, density, initial yield stress, ultimate tensile, maximum allowable effective plastic strain.
It was performed a contact analysis between the body structure and the pendulum. There were modelled like 3D contact surfaces only a part of the cab corner and the surface of the cylinder. Between the contact surfaces was considered the proper frictional coefficient.

3. THE PREDICTION OF THE STRUCTURES BEHAVIOUR

The crash process is calculated using a transient dynamic analysis with a very little time step (even 10^{-6}s). A deformation process of 100 ms needs 10^{5} time steps. The solution is calculated in few hours if the computer is not a fast one [1].

In the first stages, the pendulum is accelerated under the gravitational forces. The maximum velocity is obtained when the pendulum hit the structure. After the impact the velocity of the pendulum is decreasing rapidly. The simulation must be performed until the velocity became zero.

The effective stresses are rapidly increasing especially in the impact zone and in the structure of the body. Is important to study the evolution of the effective stresses in the cab structure (Figure 4), to observe the areas where are surpassed the initial yield stress or the ultimate tensile, or to observe the accumulated effective plastic strain (Figure 5).

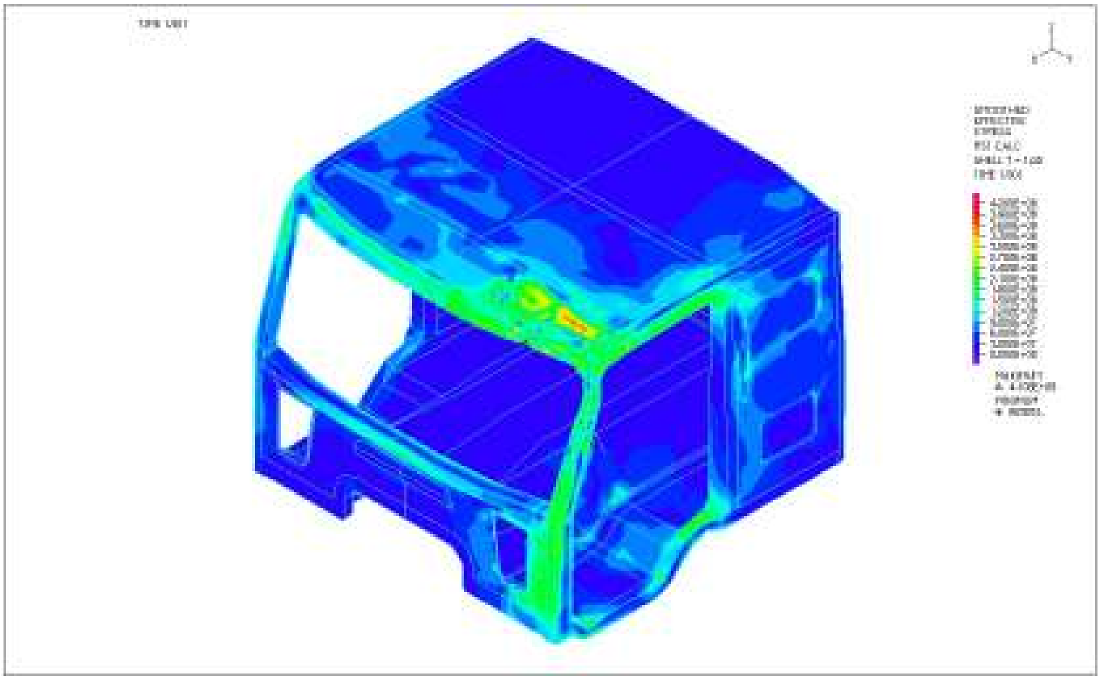

Figure 4: The effective stresses in the cab structure

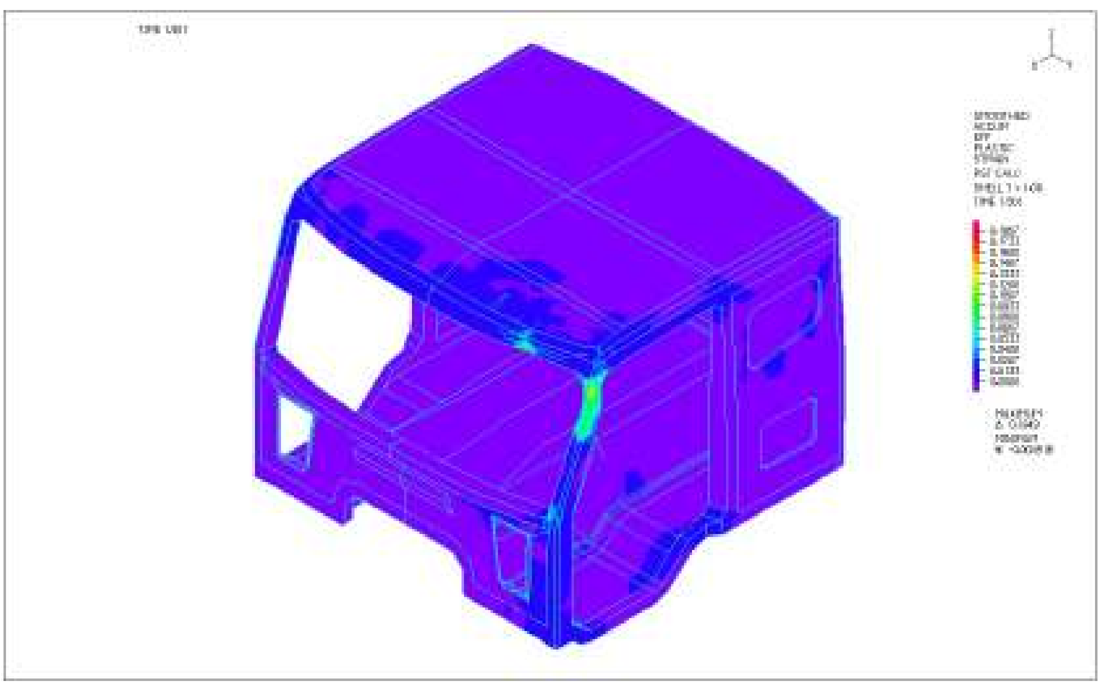

Figure 5: The accumulated effective plastic strain in the cab structure

In the bus case, it is possible to observe step by step the plastic deformation processes of the structure.
It was observed that the maximal plastic strain was reached in the first steps, when the kinetic energy is transformed in plastic deformation energy and the corner is crushed. When the velocity decrease the plastic deformation is limited in the corner zone.
It is very important to observe the evolution of the effective stresses. If is exceeded the ultimate tensile the structure could be cracked. The crack must not appear in essential zones that could affect negatively the behaviour.
After the crash of the corner, the effective stresses increase on the middle of the lateral pillars, especially in the connection nodes of the structure.
The plastic strain indicates where the structure is plastically deformed. The manufacturer can observe where the structure might be reinforced to obtain better rollover behaviour.
Very important is to observe if the deformed structure penetrate the defined survival space. Is not accepted any penetration of this space (Figure 6).
Of course, it is possible to make the movie of the deformation process.

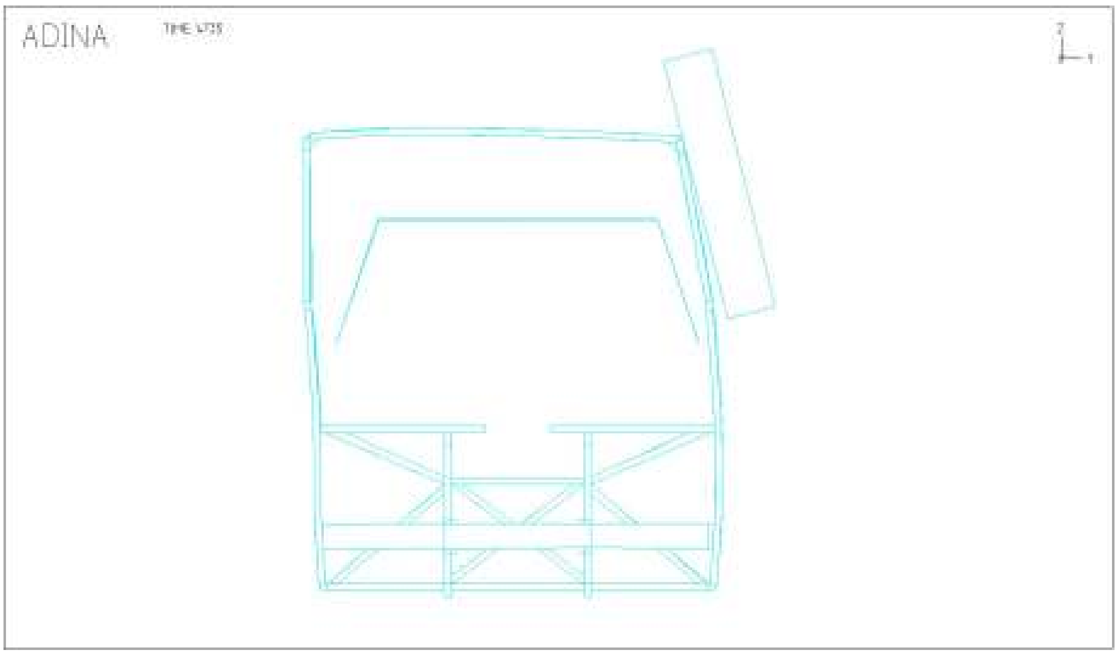

Figure 6: The deformation of the bus structure

4. CONCLUSION

The method could be successfully used to predict the impact behaviour of a vehicle structure. Is possible to observe the deformation of the structure, all the areas which could be affected by the impact and how the impact loads are transmitted throw the mounting systems to the chassis frame.

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