Studies About the Front Bumper Performance During a Pedestrian Leg Impact

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Abstract. A continuous evolution of requirements and standards sheds over the development of new vehicles (for example EuroNCAP ratings) in order to create competition between same market models customer related.

The pedestrian impact protection has to be permanently improved as the damage of the front end structure of the vehicle to be reduced to minimal.

The European Community has had impressive success in achieving the highest pedestrian protection level on the globe. In 2013, 5.712 pedestrians were killed in road accidents in the EU, which is 22% of all fatalities. In the last decade, in the European Union, pedestrian fatalities were reduced by 37%, while the total number of fatalities was reduced by almost 45%.

The front end structure, including the bumper, responds for the absorption of the kinetic energy created during the impact with maximum efficiency in order to avoid the large deformation of structural components and good behavior during a pedestrian impact. This is only one of the constraints that the front end structure has to cope with, additionally we can mention the dimensioning of the front end of the vehicle which can affect the packaging, which is mainly influenced by the design, styling and the pedestrian requirements intended to be accomplished by the vehicle.

The present paper focuses on the pedestrian impact, offering an overview over the actual state, the load configuration, the applicable regulation, the challenging requirements of a modern front structure, which the modern bumper has to comply with and the finite element simulation of this kind of test.

Keywords: Pedestrian impact, finite element analysis simulation, EuroNCAP

1 Introduction

Recently, based on the help of advanced development of software and hardware equipment for numerical simulation, the period of time in which a project is finished and a new car is launched on the market has become smaller and smaller. The competition on the automobile market has lead constructors to seek, apply and improve the latest techniques in the car manufacturing.

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The numerical simulation has gained more and more terrain facing the need of cost efficiency and rapidity of the project development. After the manufacturing, a car has to pass in the first place the requirements of the homologation agencies and secondly, the very popular ranking tests (EuroNCAP). Potential problems, which can affect the quality of the product over its life are identified and removed during the project phase.

Using virtual prototyping and numerical simulation, we can improve the performance and the cost of the part before is it actually built. In addition to the numerical test, a physical one is carried out in addition to the numerical one in order to validate that the part meets the requirements. As a consequence, the need to build several sets of physical prototypes of the parts has decreased to a very small number, thus saving time and money.

The advantage of numerical simulation over the physical test consists in observing immediately if one part of the assembly does not comply with the specifications, rather than following an expensive testing procedure and waiting between the test and the post-processing of the results. Thus, we can define the needed adjustments and rerun the simulation until we obtain the desired results. More precisely, while waiting several days for the physical test results for one crash configuration, we can numerically test hundreds of parameters simultaneously while observing in real time the global effects. If it shows that with the current front bumper design it is impossible to attain the required performances, a geometry change can be proposed.

2 Traffic safety facts

The European Community has had impressive success in achieving the highest pedestrian protection level on the globe. In 2013, 5.712 pedestrians were killed in road accidents in the EU, which is 22% of all fatalities. In the last decade, in the European Union, pedestrian fatalities were reduced by 37%, while the total number of fatalities was reduced by almost 45%.

In figure 1 is presented the evolution of the pedestrian causalities between 2004 and 2013 in European Union.

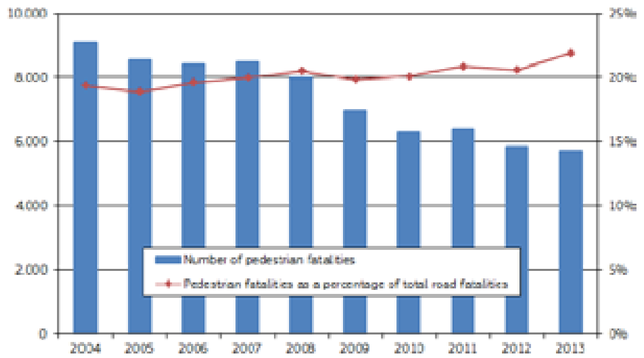

Fig. 1. Number of pedestrian fatalities and percentage of all road fatalities in European Union, 2004-2013 [5]

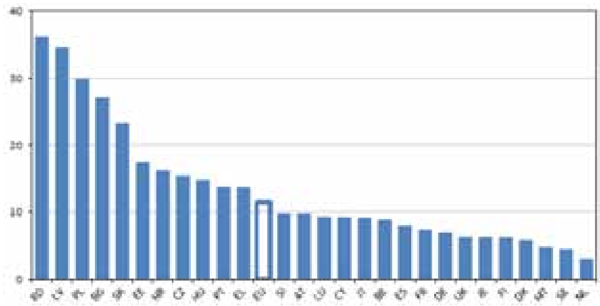

Fig. 2. Pedestrian fatality rates per million population by country, European Union, 2013 [5]

The rate of pedestrian deaths in European Union countries varies from 3 pedestrian fatalities per million population in the Netherlands to more than 35 pedestrian fatalities per million population in Romania, a rate about 12 times higher.

3 Pedestrian regulations

A pedestrian crash can usually be divided into 4 stages: the car initiate the contact with the pedestrian by touching his leg (tibia) with the front bumper, the frond edge of the bonnet or headlight hits the upper leg (pelvis), the head of the pedestrian hits the bonnet or the windshield, the pedestrian is projected in the air and hits the ground.

For the first three type of pedestrian impact are described in the European Commission Regulation, each using different sub-systems impactors to represent the main phases of a car-to-pedestrian impact. The three types of impactors are:

- A legform impactor representing the adult lower limb to indicate lateral knee-joint shear displacement, bending angle and tibia acceleration, caused by the contact with the bumper
- A upper legform impactor representing the adult upper leg and pelvis to record bending moments and forces caused by the contact of the bonnet leading edge
- Child and adult headform impactors to record head accelerations caused by the contact with the bonnet

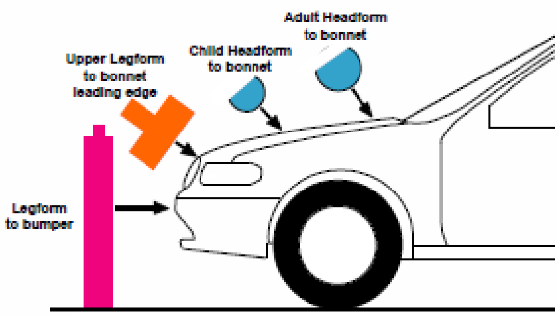

Fig. 3. The sub-system tests used in EC directive [2]

A more exigent approach is conducted by the EuroNCAP program. The targets in this case are much lower and more criteria is analyzed during the physical tests.

Also after the trial is conducted, each vehicle receives a score that finally contributes to the global rating of the car. Below is an example of the scoring configuration for EuroNCAP.

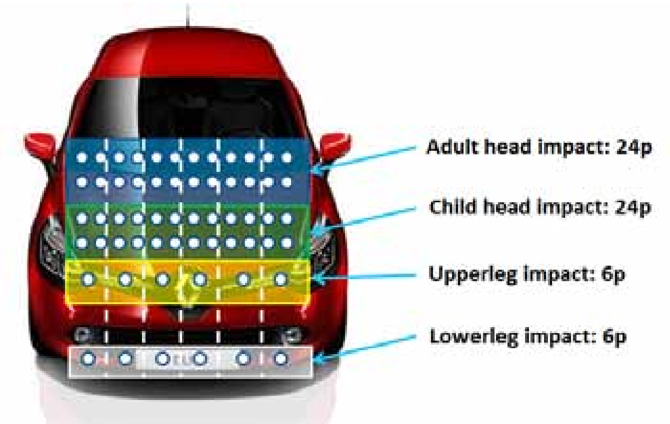

Fig. 4. EuroNCAP scoring configuration

4 Pedestrian finite element simulation

For researching the pedestrian impact it was used a finite element model composed of a simple front beam made from steel with a thickness of 1mm. It were launched two simulations to evaluate the difference in behavior between a classic solution of body in white front end and a modern one.

The impactor used for this trial consists of a metal center beam surrounded by two sheets of foam. The total mass of the striker is calibrated to 9.5kg, as the EC directive describes. The imposed initial speed was set at 40km/h and the impactor guided along X axis.

The results that will be analyzed are the force that is measured in the contact between the impactor and the crossbeams and three section moments (superior, center and inferior).

Requirements set to be respected by this type of test are 675daN for axial contact force and 450Nm for moment sections.

The models used in simulation can be observed in the following pictures.

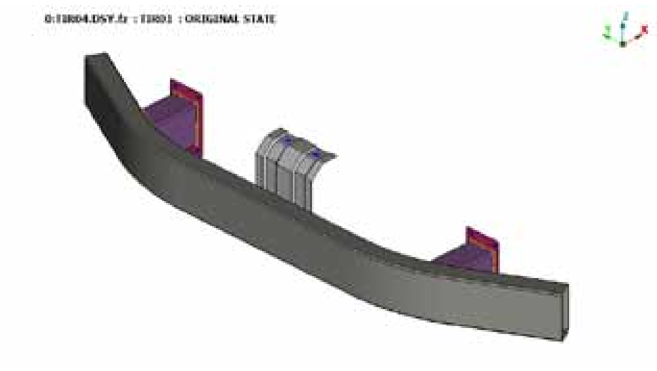

Fig. 5. Classic crossbeam model

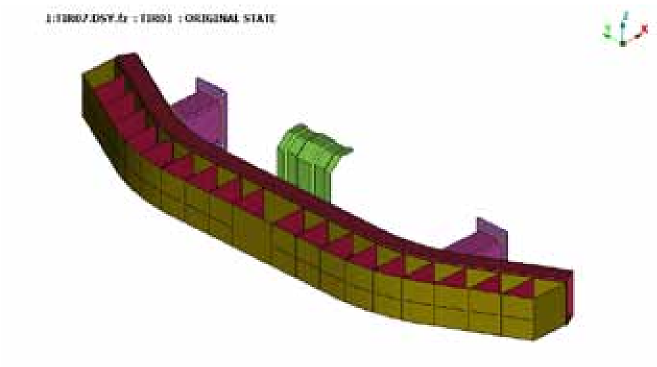

Fig. 6. Modern crossbeam model (with shock absorber)

In the final state we can observe that the presence of the shock absorber reduces the risk of the legform hitting a hard structure component. The maximum plastic deformations for the two models can be evaluated in the following pictures.

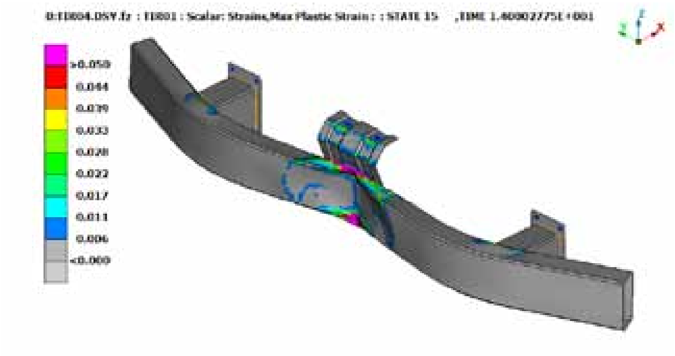

Fig. 7. Classic crossbeam model – plastic deformation

In this case probably the pedestrian will be hardly injured. Also the deformations of the structure in this case can lead to greater values of the forces and moments that are defined to be respected in the regulations.

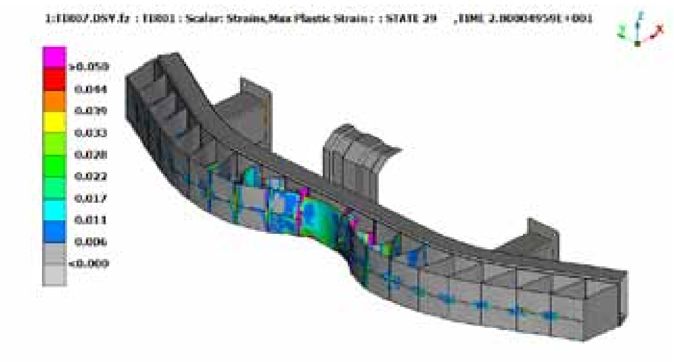

Fig. 8. Modern crossbeam model – plastic deformation

The shock absorber has a good behavior and it manages to distribute the force to a greater surface of the crossbeam. Also, by deforming itself it absorbs a big part of the energy that does not reach the crossbeam.

The difference in deformation (mm) is very high between the two solutions, for the classic solution were identified 70mm in comparison with only 3mm measured for the modern configuration.

The values of the modern solution measured for the force and moments can be identified in the figure below. They don't exceed the limits imposed and are well distributed during the impact, assuring in this manner a good characteristic.

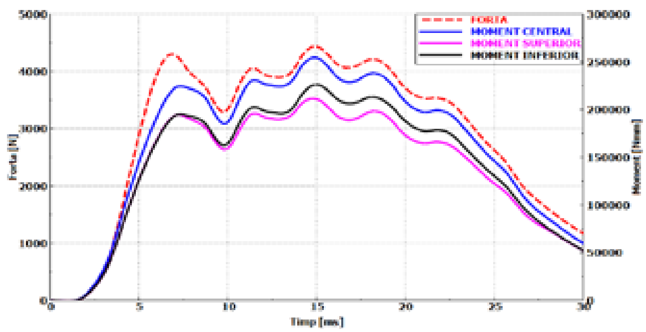

Fig. 9. Modern crossbeam model – force and moment

5 Conclusions

The exigencies of the pedestrian regulations are constantly increasing worldwide, by imposing greater objectives by institutions like GlobalNCAP, EuroNCAP or NHTSA.

This fact has a huge impact over the future of automotive design, the front bumper being an element that is always reshaped in order to comply with the challenging architecture of the vehicle. This paper offers a very fast calculation alternative for numerical simulation with the help of a simplified model, allowing to optimize quickly the volume available for a front bumper absorber in order to comply with the actual requirements. The results show good correlation in terms of deformation and values obtained for moments and forces. For future work, it is very important to compare the shape of the curves and the overall values with the full-scale physical model results.

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