Lateral Impact Behavior Study of a Car Door

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Abstract. Side impact collision is one of the most important challenges faced today by the automotive industry. This leads to a significant interest in the field of side impact protection by international car manufacturers and regulators. This article will present and study the effects produced during a lateral impact on a small impact area, the lateral impact with a pole impact. In the real world, impacts on small surfaces are collisions with rigid objects along the roadside, for example, trees and pillars. These accidents are dangerous and the frequency of deaths or serious injuries due to lateral impact is high. Studies have shown that the main cause of injury to persons in side impact collisions can be attributed to unwanted intrusion of a side panel in the passenger compartment. Nearby occupants are four times more likely to suffer serious or fatal injuries. The lateral impact is modeled on the passive safety rules that make the study base of a European organization, Euro NCAP. The primary objective in side impact is to maximize energy absorption and minimize injury to the occupant.

Keywords: Car body · Side door · Impact analysis · FEM

1 Introduction

The technical evolution in the automotive industry imposes requirements for the development of lighter and more efficient cars, which are subject to increasing safety requirements. Passive safety aims to optimize vehicle features to eliminate or mitigate the consequences of road accidents, even during their production. The aim is to ensure the protection of both the occupants of the vehicle and of the other road participants (pedestrians, cyclists, etc.) [3].

The side doors for cars are components that close, which are articulated on the resistance structure and are designed to open and close the passenger compartment in order to allow them access inside. Side doors can also help improve the body impact on frontal and lateral impacts by introducing special reinforcements into their structure. The impact resistance of the side doors is important because it contributes to the integrity of the passenger compartment both in the lateral impact and the front impact through the beams provided in their structure [1].

In case of lateral impact, the size of the contact surface can greatly influence the energy taken over by the body structure. When the impact surface is small, i.e. a pole, the door takes up much of the impact energy. In the first part of the impact, the door is

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pushed towards the door frame and the side panel of the passenger compartment, the outer panel being deformed. To prevent the door from bending and slipping alongside the door frame, it is necessary to increase the bending strength of the door. This can be achieved by inserting one or more beams with different profiles between the two door panels in a horizontal or sloping direction, its exact position depending on the location of the hinges, locks and other features of the door. The closer this bar is placed near the door sills and the door will be prevented from sliding past the sills [1].

Generally, the doors are constructed out of two panels, an inner panel and an exterior panel, assembled by applying a structural adhesive and crimped all over the side door. A limited number of welding points can also be made. The window frame serves to provide the channel that the window glides in, but also to increase the torsional stiffness of the door. The reinforcement panels are applied to stiffen the area where the joints are attached or to make the front and side beams provided in the door [2] (Fig. 1).

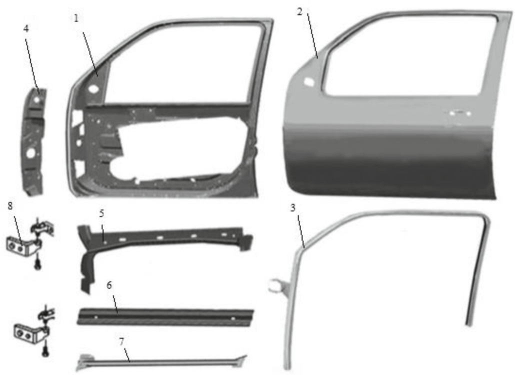


Fig. 1. Structural elements of a unitary door [2]. Legend: 1 - outer panel; 2 - inner panel; 3 - window glide channel; 4 - hinge reinforcement; 5 - upper inner belt reinforcement; 6 - outer belt upper reinforcement; 7 - anti-intrusion bar for lateral impact; 8 - hinges

2 General Design of the Side Door and Simulation of the Lateral Side Impact with a Pole

2.1 Geometrical Modeling

The geometric design of the 3D side door model for the car was made using the Ansys program. For the simplified modeling of the door model presented in this project, a Dacia Logan car door was chosen as a similar model (Fig. 2).

The modeling of the material from which the side door is made is required to perform the resistance calculations. From the "Engineering Data - General Non-linear Materials" module of the Ansys R 15.0 design software library, "Structural Steel Non-linear" was chosen.

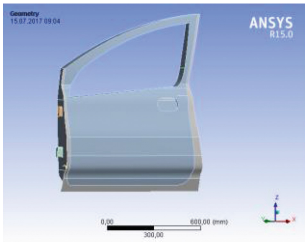


Fig. 2. The 3D door model

The properties of the material for the side door:

- Density, $\rho = 7.85$ g/cm^3;
- Poisson' ratio, $\mu = 0.3$;
- Young's Module, $E = 2X10^5$ MPa;
- Yield strength, $\sigma_c = 250$ MPa.

2.2 Model from Finished Elements

To create the finite element network are used the options within the "Mesh" subcategory. The program offers the possibility of choosing the distance between network nodes or using default values [1]. The finite element network consists of 5701 nodes and 5764 elements (Fig. 3).

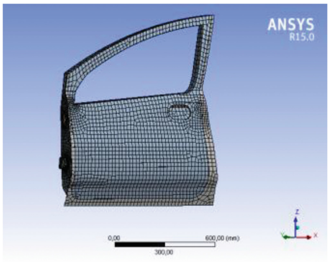


Fig. 3. Finite element network of the side door model for cars

2.3 Initial Conditions for Side Impact Simulation

The study and behavior of the lateral doors during the side impact with the impact pole takes place in view of the simulation conditions and the level of testing underlying the Euro NCAP test body.

Euro NCAP is a European Automotive Performance Assessment Program, based in Brussels (Belgium) and set up in 1997 by the Transport Research Laboratory of the Department of Transport, England. The program is modeled after the New Car

Assessment Program (NCAP), introduced in 1979 by the National Highway Traffic Safety Administration [4] (Fig. 4).

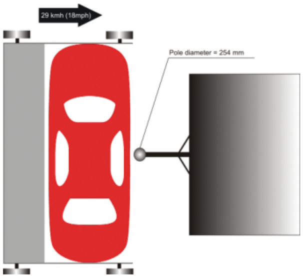


Fig. 4. Lateral impact using a lateral pole [4]

The initial conditions imposed on the door model are:

- Simplified Geometry - 3D door model was made of variable thickness surfaces.
- The impact pole has a diameter of 254 mm and is projected perpendicular to the surface of the door panel at a speed of 29 km/h. The impact pole is defined as a rigid body, so that during impact the material does not deform under the action of mechanical stresses.
- The door is fixed to the outer edge.
- It is proposed to modify the material density for the impact pillar up to $\rho = 15\ g/cm^3$, representing a 50% increase in material density. As a result of this change the mass of the impact pole is $m = 1136$ kg.
- The kinetic impact energy of the pole must be equal to the kinetic impact energy of the car that strikes a pole.
- Conditions imposed on the degree of freedom (Fig. 5).

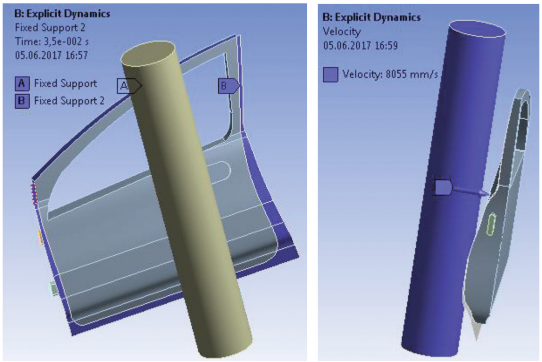


Fig. 5. Side door support points and force applied to the impact pole

2.4 Side Impact Study

The impact simulation results will be evaluated by the values corresponding to the equivalent plastic strain of the material and by the values corresponding to the total deformation in the area of interest.

The equivalent plastic strain of the material is characterized by the relation:

$$\varepsilon = \frac{\Delta L}{L_0} \tag{1}$$

The behavior of the door in the event of lateral impact will be determined by two methods:

1. For the first set of impact strength tests, consider the door model without the elements that underlie the interior door structure, the upper belt reinforcement and the anti-intrusion bar.
2. For the second set of tests, it is proposed to model U-shaped inner bars. That have the role of increasing the energy absorption during impact.

The experimental results for the door model without interior reinforcement of the door shown in Fig. 6. The value of the equivalent plastic strain is significant, with the maximum point ε = 0.0564. Around the outer panel, according to the taken sample, the maximum value of the equivalent plastic strain has an approximate value of ε = 0.0537.

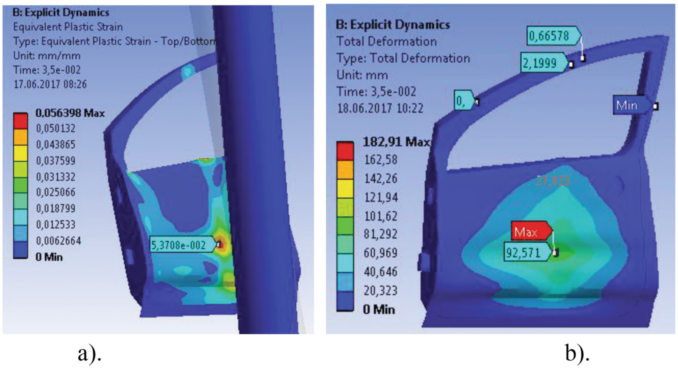
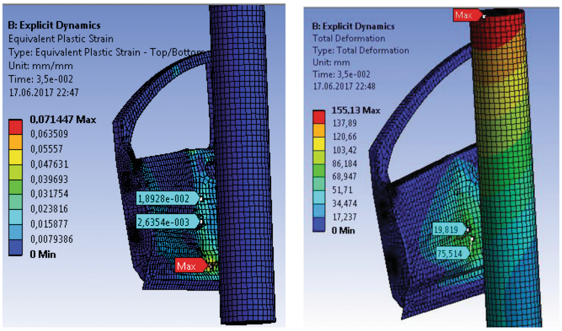


Fig. 6. (a). Equivalent plastic strain (b). Total deformation of the door without anti-intrusion bar

The results of the total deformation obtained by impact with the lateral pole is characterized by the value, δ = 92.57 mm. In the area of the window frame, the deformation is slightly above the 2 mm maximum limit.

Next, it is proposed to analyze the side impact simulation on the door, in which the interior reinforcement was designed. Then, the results obtained for the second set of tests are shown in the following figures.

Because of the modifications made to the study of the model construction, a considerable improvement in the door behavior during the impact is observed in Fig. 7. This improvement is evidenced by the numerical value of the equivalent plastic strain in the outer door panel area, ε = 0.0189. The sample of the equivalent plastic strain taken directly from the anti-intrusion bar records a very low value compared to the posterior panel, ε = 0.0026. The anti-intrusion bar performs its role very well, reducing the total lateral deformation of the side door by approximately 20 mm.



a). b).

Fig. 7. (a). Equivalent plastic strain (b). Total deformation with anti-intrusion bar

During impact the pole gains another degree of freedom, rotating around the Z axis and hitting the window frame. To avoid this rotation movement of the pole around the Z axis during the impact, the degrees of freedom of the pole will be constrained, Fig. 8. It will move only in the direction of the Y axis. A new set of tests for the door impact study will be initiated.

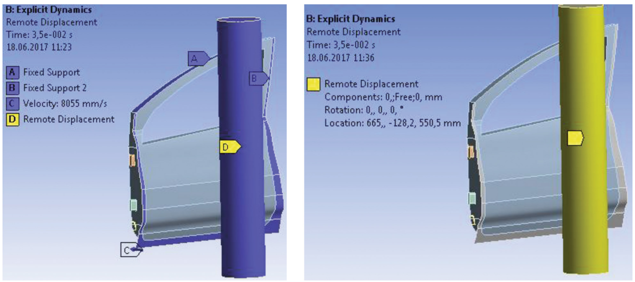
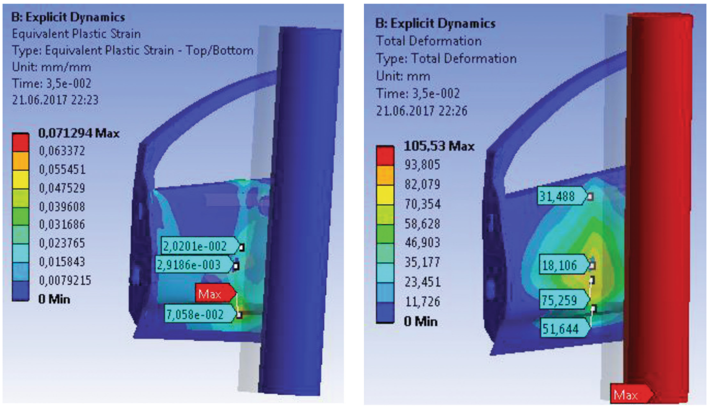


Fig. 8. Initial conditions defined for impact simulation

In this case, Fig. 9, it is observed that the structure of the side door has a linear behavior in relation to the impact pole during the plastic deformation process. The maximum value of the equivalent plastic strain is recorded in the center area of the outer panel, defined as the main study area. It is noticed that the impact pole keeps the direction of travel in the direction of the Y axis.



a). b).

Fig. 9. (a). Equivalent plastic strain (b). Total door deformation resulting from the impact with the anti-intrusion bar and constraint of the pole

Following the comparisons between the results of the above tests and the results from the last simulation, it is noted that the differences between the results are not significant. In this case, the constraint of pole freedom degrees only in the Y axis direction does not significantly affect the results. The differences between the results from the total deformation simulations are in the order of the decimal.

3 Conclusions

The purpose of elaborating this project was to study the side door behavior during a lateral impact with a pole (Table 1).

Table 1. The characteristic values of impact simulations of the side door

Case	Structure of door side	Total deformation δ (mm)	Equivalent plastic strain ε (–)
1	Door model without anti-intrusion bar	92.57	0.0537
2	Door model with anti-intrusion bar	75.51	0.0189
	Anti-intrusion bar	19.819	0.0026
3	Door model with anti-intrusion bar and constraint of the pole	75.2	0.02
	Anti-intrusion bar	18.1	0.0029

To determine the behavior of the side door and verifying its resistance conditions in case of lateral impact, the first tests implied a door model without the usual reinforcement beams inside the two panels. After the simulation, we highlighted the resulting values for the total deformation and the equivalent plastic strain of the lateral door. For the second set of tests on the door model, a horizontal upper belt reinforcement bar was introduced, and another anti-intrusion bar on a sloped position. Both bars have a U-shaped profile with different dimensions.

The purpose of these two types of trials is to compare between the two models, to highlight the importance of door reinforcements and to study the behavior of lateral doors when subjected to a lateral impact.

According to the results, the anti-intrusion bar reduces the total door deformation with approximately 20 mm. Through this improvement, the importance of internal structures inside a lateral door is validated.

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