POLITEHNICA University of Bucharest

Doctoral School of Transports

DOCTORAL THESIS

Automotives passive safety research

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BUCHAREST

2021

Abstract

***Keywords**: passive safety, frontal impact, side impact, mathematical models, Matlab Simulink, total deformation, Ansys, equivalent plastic strain.*

In order to improve the passive safety of motor vehicles, the behavior of vehicles on impact is a complex and important issue in the automotive industry. Efforts to increase the safety of vehicles focus on protecting the driver and passengers from the effects of a collision.

The passive safety system is represented by all measures that help to eliminate or reduce the effects of traffic accidents.

In the first three chapters of the paper were made several summaries on: the evolution over time of increasing car safety through the introduction of active and passive safety systems; the current state of legislative regulations on passive safety; the current state of research on the construction of car bodies to increase occupant safety.

Regarding the current state of research on the construction of car bodies to increase the safety of occupants by creating a rigid structure around the passenger compartment that is able to ensure a minimum survival space for occupants during an impact. Also, in order to ensure the integrity of the passenger compartment, the resistance structures of the car surrounding the passenger compartment must be constructed in such a way that, during an impact, they can deform and take up a large part of the impact energy.

Also, for the protection of passengers, restraint systems (seat belts, airbag system and seats) have been developed that have the role of ensuring and protecting occupations during an impact.

Furthermore, several modeling and simulation environments for the study of vehicle collisions were analyzed by developing several simple and complex mathematical models for the study of the collision between two bodies. To solve these mathematical models, simplified schemes were developed, which were solved using the modeling and simulation environment offered by the Matlab Simulink program, starting from Lagrange's generalized equation.

Regarding the results obtained after solving the one-dimensional mass-spring model, the total deformation of the vehicle structure at a speed of 50 km/h does not exceed the value of 700 mm.

Regarding the solution of the model with two degrees of freedom, consisting of two bodies, it was solved by two methods. In the first case it was considered an equivalent system of mass-spring type, and in the second case it was considered an equivalent system of mass-spring-damper type. Finally, in order to study the phenomena and the differences that appeared between the two cases, the relative displacements, the relative speeds and the relative accelerations were represented graphically, in parallel.

The deformations in the case of the mass-spring calculation model are higher than those recorded in the case of the equivalent mass-spring-damper model.

Following the solution of the model with n degrees of freedom for the study of the frontal impact with a non-deformable barrier, the deformation of the front compartment structure during an impact produced at 50 km/h is approximately 600 mm. In this case an equivalent mass-spring system was considered.

Regarding the resolution of the model with n degrees of freedom for the study of the frontal impact on 40% of the frontal surface with a non-deformable barrier, the deformation of the front compartment structure during an impact produced at 50 km/h is about 700 mm.

The solution of the model for the study of the side impact with a rigid pillar on a side door, the deformation of the structure during an impact produced at 32 km/h is about 210 mm.

Also, for the study of the behavior of the vehicle structure during an impact, several 3D geometric models were developed in the Ansys program. Solving these mathematical models was done using the finite element method.

The results obtained, after solving the one-dimensional model using the finite element method, for the total deformation of the vehicle structure at a speed of 50 km/h is about 330 mm. Comparing the results of the two one-dimensional models (mass-spring model and 3D model) it is observed that the deformations of the structure obtained by modeling and simulation with finite elements are smaller than those obtained from the mathematical calculation model.

By solving the model with n degrees of freedom for the study of the frontal impact on 40% of the frontal surface with a rigid barrier using the finite element method, it is desired to perform studies on the frontal impact behavior of the front compartment structure at different speeds. The initial speeds of the vehicle before the impact take values from the range, $V_{initial}$ = [4, 10, 20, 23, 25, 50] km/h.. The value of the deformation is lower compared to that obtained by calculating the mathematical model of mass-spring type.

Following the solution of the mathematical model for the study of the side impact with a rigid pillar using the finite element method, the total deformation of the door is approximately 75.2 mm.

Finally, it is proposed to model and simulate several sections of the impact absorption blocks in order to study the frontal impact behavior with a speed of 10 km/h. Following the tests, it is observed that the block with a cylindrical section deforms approximately 45.5 mm, the one of hexagonal section deforms approximately 54.4 mm. Regarding the rectangular sections, the smallest deformation is registered among the three cell section, followed by the unicellular section and finally the two cell section.

The last part of the paper presents the modeling and simulation of two seat structures for vehicles in order to test the anchorage points of the seat belt, according to Regulation no. 14 UNECE.

The results of the tests on the anchorage points of the safety belt shall be evaluated by the values corresponding to the relative plastic elongation of the material and by the values corresponding to the total deformation. The total registration deformations are: δ = 297.5 mm for seat model 1 and δ = 207.97 mm for seat model 2. Also, regarding the results of the relative plastic elongation, samples were taken from the anchorage points of the seat belts and the indicated value is $\varepsilon = 0$. In conclusion, no specific plastic deformations appear at the anchor points of the seat belts.

In the last part of the paper, in order to highlight the degree of safety offered to the occupants and to validate the mathematical models regarding the resistance of the seat belt anchorages, experimental tests are carried out in accordance with Regulation No 14 UNECE. Two seat models were tested for the strength of the seat belt anchorages. These were tested simultaneously using parallel force composing devices. The traction devices are placed on the seat cushion and are pressed into the seat back. The seat belt in the pelvic area is positioned above the device pressed into the seat back, tightening tightly around it. The role of the upper device is to support the seat belt in the chest area.

In order to highlight the degree of confidence of the realized models, the results obtained by modeling and simulation were compared with those obtained experimentally.