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Study and modelling of the passenger safety devices of an electric vehicle by finite elements

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Abstract

Electric mobility gets mainly involved quadricycles and cars. Between these two vehicle types there are differences in terms of stability, performance, cost, autonomy and safety. The authors studied the implementation of passenger safety devices on a prototype for an electric vehicle derived from a heavy quadricycle. A finite element analysis starting from experimental results was carried out in order to determine the effectiveness in case of frontal and side crashes.

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1. Introduction

Nowadays electric mobility is an attractive challenge because of its low environmental impact. Furthermore, small dimensions of the vehicle are researched in order to move in the cities. Electric Ultra-Light vehicles (ULV) match these requirements although their low safety performances stated in EuroNCAP (2016). This work aims to evaluate the possibility to improve the passenger safety of an ULV prototype deriving from a heavy quadricycle. The car would cost more than a heavy quadricycle and less than a small electric car and has a pioneering tubular chassis

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presented in Centro Studi Internazionali (2016) which induced the authors to establish the position of the curtain airbag.

Finite element models were used in order to simulate frontal and side impacts. Numerical simulations are indeed recently used in passenger safety studies because they allow the repeatability of the tests without high setup costs as declared in Hayashi and Taylor (2014).

In the 1960s some automotive engineers began to develop lumped element models mentioned in Leonardi (2012) in order to study vehicle dynamics. Kamal (1970) for example modelled a car with masses, springs and dampers. According to Pawlus et al. (2011) this model was simple but the estimation of the parameters for each component was a critical issue. Moreover, Leonardi (2012) highlighted the experimental data had low accuracy because of the devices.

In the 1970s in the aerospace field the Finite Element Analysis (FEA) was raising as demonstrated by Hughes (2000) and in the 1990s, FEA was being used in order to verify experimental data, as reported in Leonardi (2012).

Leonardi (2012) stated that the producers tried to find a way in order to reduce the production costs and Hill (2007) pointed out that a large amount of the cost was due to engineering and testing. The reduction of physical experiments was a possible solution: for a car, more than twenty tests are carried out and each one costs around 650.000 dollars as stated in Leonardi (2012).

According to Leonardi (2012), nowadays FEA and experimental tests were still carried out. In Teng et al. (2008) a multibody model of the occupant was used and a comparison between this model and a full-scale in LS-DYNA3D was executed. A multibody model of a vehicle was instead presented in Pawlus et al. (2011). Here the front part of the car was divided in six nondeformable components attached each other with springs and dampers. This model is worth only for frontal impacts at low speed supposing that the front part of the car is the only deformable zone in these types of crash.

Because of the high dynamics of the studied phenomena, explicit methods are commonly used as demonstrated in Midjena and Muraspahic (2013) and Borovinsek et al. (2009).

In the models presented in this work the belts were modelled, the airbags were instead designed. The combined action of these devices is strictly necessary because the airbag deployment could hurt the passenger as stated in Barman et al. (2008).

Furthermore, only the components of the car nearby the driver were in the models. In this way, an optimization of the computational cost was reached.

Nomenclature

x	longitudinal direction of the car, positive from the rear to the front
y	transversal direction of the car, positive from the passenger seat to the driver seat
z	vertical direction of the car, positive upwards
Δt	time step [s]
P_{ext}	pressure outside the airbag [Pa]
ΔP_{def}	difference of pressure for the opening of the vent holes [Pa]
a_R	head acceleration [g]

2. Materials and methods

An ODB (Offset-Deformable Barrier) crash and a SMB (Side Mobile Barrier) crash were simulated in the laboratory. During the tests, the accelerations of interesting points of the car were recorded. The dummy was not instrumented.

HyperMesh and HyperCrash were employed for the pre-processing activities, HyperView and HyperGraph for the post-processing. The calculation was carried out using an explicit method (Radioss). This scheme is conditionally stable and for this reason, the time step has to be less than a critical value. The user can manually define a critical value. When the calculated time step becomes less than the user-defined value, mass scaling occurs.

Shell3n, Shell4n, Tetra4 isoparametric elements were used. Rigid elements were employed for the connections.