ANALYSIS OF THE AIRBAG DEPLOYMENT IN FRONTAL IMPACT OF ADAPTED VEHICLES FOR DISABLED DRIVERS

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Abstract: The car control adaptations are used in vehicles to facilitate the driving to handicapped people. Passive safety in these vehicles has to be maintained. In order to analyze this relation, simulation models are generated. The methodology used to generate this simulation consists in these phases: to develop the three-dimensional model of the driving place, to import the model to the finite elements software, to generate the mesh and to assign the most important characteristics like material properties, contact interfaces, gas expansion models, airbag fold types, etc. and finally to analyze how the deployment is.

1. INTRODUCTION

An increasing number of components are used in vehicles. These components reflect a functional design that meets various requirements such as passive safety. These requirements should also be met by any control adaptations fitted to enable disabled people to drive. While the main requirement of these adaptations is to enable individuals with various disabilities to drive, their use need not imply a decrease in the vehicle passive safety level. Consideration should also be given to recycling these components in compliance with established environmental policies.
The redesign of these components is considered so that they meet functional requirements and increase the passive safety level for disabled drivers. The environmental repercussions of the materials and processes used in design and manufacturing are also considered.
To undertake such a redesign, the various situations that may occur are analysed – together with the passive safety devices that are currently fitted in vehicles. Load hypothesis is analysed from the functional and passive safety perspectives. Airbags and steering adaptations have an important impact on the passive safety level of a vehicle and these factors are analysed in this article.

2. OBJECTIVES

The work begins with a series of study stages in which the ultimate goal is to recover the materials used when these vehicle parts reach the end of their useful life. To analyse the behaviour of these adaptations in normal service, as well as in the event of an accident, the various loads to which these adaptations are subjected must be studied.
This study will verify the levels of force to which these adaptations are subjected in normal use. This will give rise to the establishment of several loading hypotheses which will facilitate the design of these adaptations from a functional perspective – the applied loads being those considered worst from the functional point of view.
Moreover, during the redesign of these adaptations those loads which are caused by passive safety devices fitted on the vehicle should be specified. In addition to verifying how these adaptations are affected, it is essential to assess whether these adaptations reduce the passive safety of the vehicle. A growing number of devices are being fitted to prevent injury in the event of an accident. Therefore, the assembly of these devices must be examined to see if they affect passive safety. Steering wheel airbags are a clear example. These devices can subject adaptations to high loads that can cause their deformation or breakage. In addition, the safety function of an airbag may be affected by these adaptations if they intrude into the passenger safety cell.

3. METHODOLOGY

The process used to evaluate the adaptations and assess the need for a redesign is a finite element software simulation of the dynamics of the model of the accident [1]. To achieve this, analytical models are available which have been calibrated and homologated for impacts, impact barriers, as well as impacts on dummies that simulate the vehicle occupants, etc.

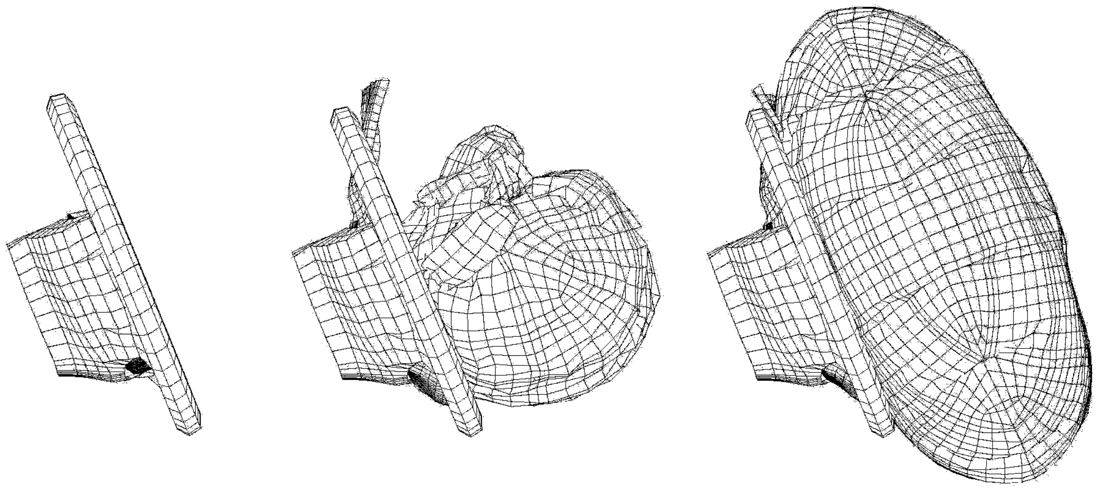

FIGURE 1. Modelling an airbag deployment

An airbag is one of the most important elements of passive safety. There are many airbag systems in use, but one of the most important airbags is the unit that prevents frontal impact. The simulation of the deployment of this airbag is a major factor in the evaluation of adaptations (Figure 1).

The methodology used to generate this simulation consisted of an initial phase in which a three-dimensional model of the driving position was developed. A commercial 3D software design package was used for this task. Once this task was accomplished, a finite element model was imported and a finite element mesh generated (see Figure 2). Finally, the main constraints of the model were specified in the dynamic simulation software – such as the materials and their characteristics, contact interfaces, gas expansion models, technique of folding the airbag, etc.

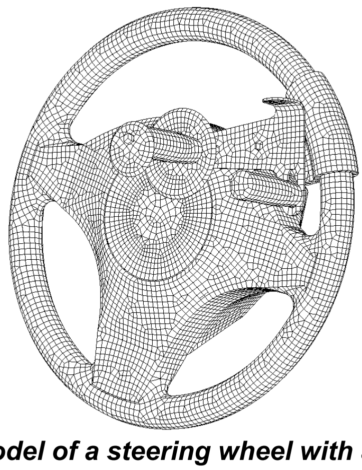

FIGURE 2. Model of a steering wheel with a double knob.

Geometric parameters from commercial vehicles which take into account the minimum distances in passenger safety cells were used for modelling the driver's position. The range was set taking into consideration that these vehicles must accommodate drivers with differing sizes and abilities. Other important factors include: the shape of the airbag, the steering wheel angle of inclination, airbag folding technique, and rate of pressure inflation.

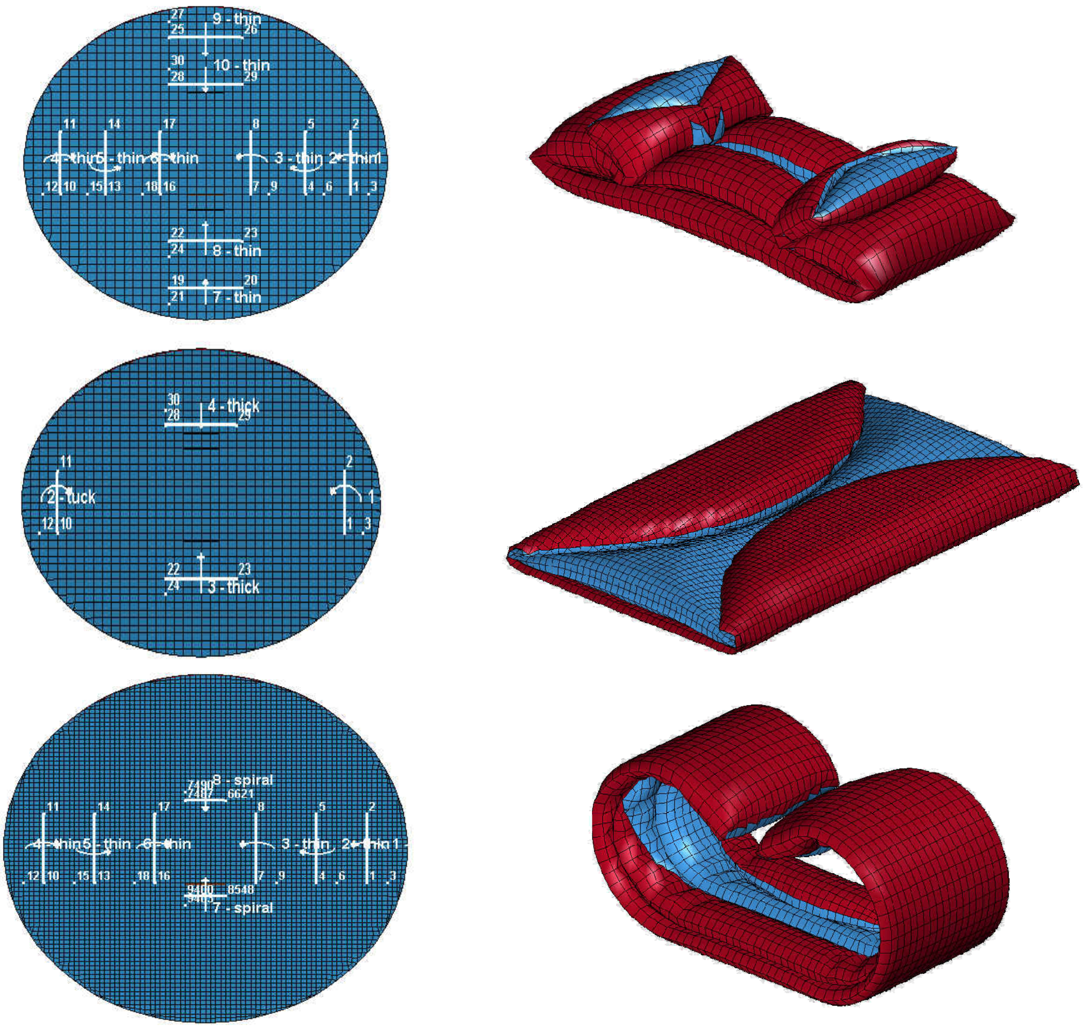

FIGURE 3. Airbag folding techniques.

Two fundamental aspects in the deployment of the steering wheel airbag were evaluated: the airbag folding technique, and the modeling of the thermodynamic gas expansion [2].
The way in which an airbag is folded is one of the factors influencing its deployment; and the folding technique also affects the time/pressure curve of the airbag. Figure 3 shows three of the folding techniques used for the simulations. These include the use of fine pleats, internal folds, and a spiral fold.
Differing models representing various laws of behaviour were used to model the expansion of the gases. The most widely used are simple, adiabatic, and hybrid.
Only the interaction of the airbag with the adaptation device was analysed. The driving position was the nominal or standard driving position, and the distance of the driver from the wheel, and therefore the front airbag, was set at the most appropriate distance for the correct functioning of the airbag. However, it is often considered that a disabled driver using an adapted device sits closer to the steering wheel than is normal.
Firstly, a simulation was made of a conventional airbag deployment on a steering wheel without any fitted adaptation. This enabled the distances occupied by an expanding airbag

to be measured, as well as with the timings. Figure 4 shows a simulated steering wheel airbag deployment sequence made using dynamic finite element software.

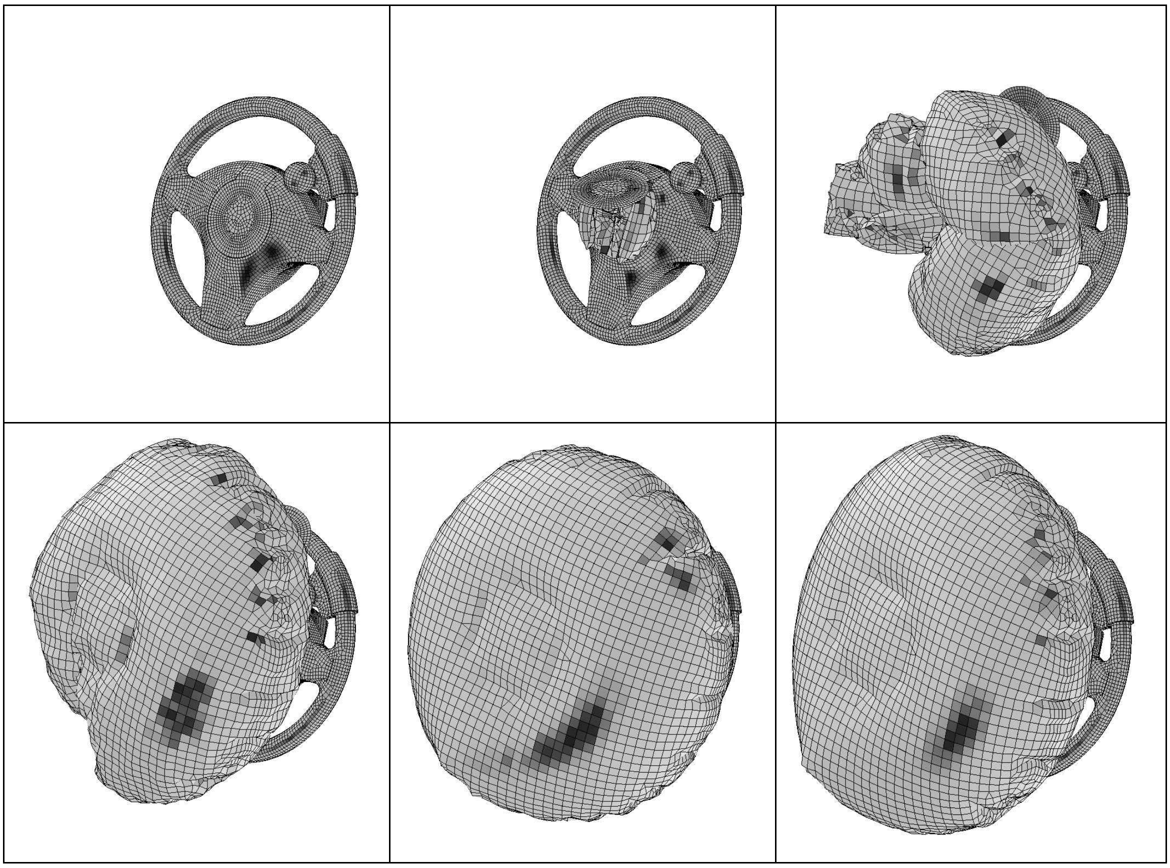

FIGURE 4. Modelling an airbag opening.

The central flat surface of the steering wheel is taken as a reference, and when the airbag inflates the distance is measured from the halfway line or the outside edge of the airbag. This measurement serves as a benchmark for subsequent analysis when the various devices being tested are fitted to the steering wheel.

If no adaptation is fitted, then the outer edge of the airbag is parallel to the steering wheel's central surface and the distance is the same in every position. Once adaptations are fitted, the minimum and maximum distances are measured with respect to the central surface of the steering wheel, in order to determine by how much the airbag has changed position.

We carried out the simulation using four different types of steering control adaptations: a simple knob; a remote control knob; a forked knob, and a double knob. These adaptations are typical of the variety available on the market, and according to a previous study on the influence of such devices on passive safety, these types of adaptations are among those most likely to interfere with the proper functioning of the frontal air bag. This interference is caused because they are clamped to the steering wheel itself and intrude on the interior space of the wheel. As shown in Figure 2, these devices can be placed in any position on the steering wheel according to the ability and comfort of the driver.

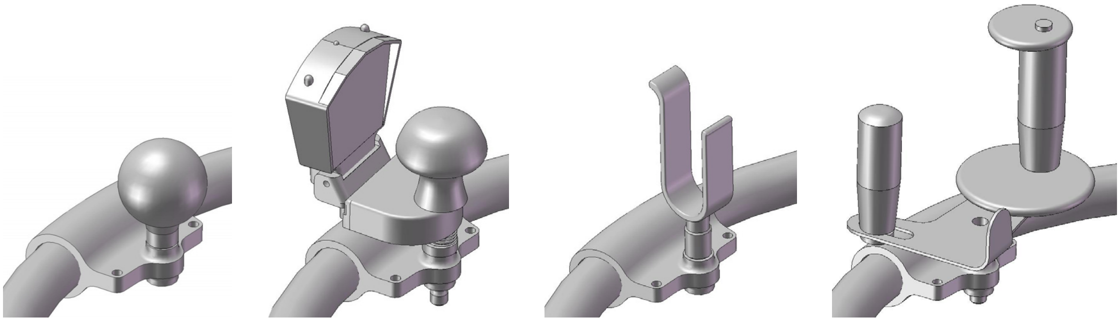

FIGURE 5. The studied adapted steering controls.

The simple knob is relatively smaller than the other devices and also interferes less. This knob enables the steering wheel to be turned with one hand. The remote control knob is larger, although it does not apparently create more difficulties than the simple knob. The remote control enables the lights, indicators, window-wipers, etc., to be activated without taking the hands from the wheel.
The forked knob is larger than the others and its design may affect the operation of the airbag. It is used in cases of tetraplegia. Finally, the shape and size of the double knob would seem to suggest that it could be the design most likely to interfere with the deployment of the airbag. This design is also used for cases of tetraplegia, where the drivers are totally disabled in the hand and wrist [3].

4. RESULTS

The pressure/time curves have been obtained from the interior of the bags (Figure 6) in order to assess the characteristics of the airbags and how they inflate.
The figure below illustrates how the pressure develops over time – from detonation to the bag being filled with air. Depending on the model used, this representation enables graphics to be produced that reveal how the bags fill and expand under pressure. A clear indication is offered by the shape of the curve during the catapult stage. This air filling process is crucial to avoid injury following an impact [4].

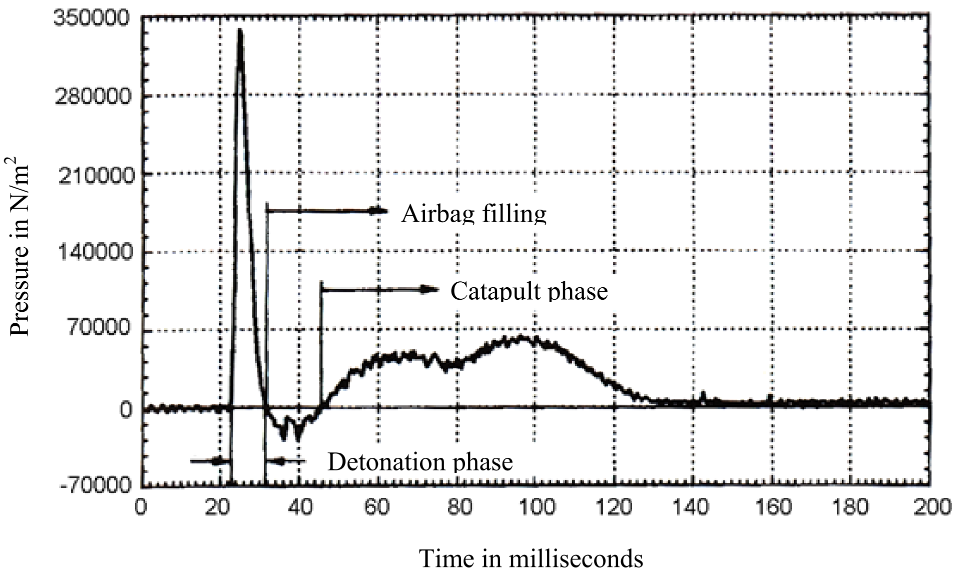

FIGURE 6. Pressure/time curve of the airbag.

Figure 7 shows one of the developed models. Representative models of airbags in action are produced by combining various folding techniques with the expansion models.

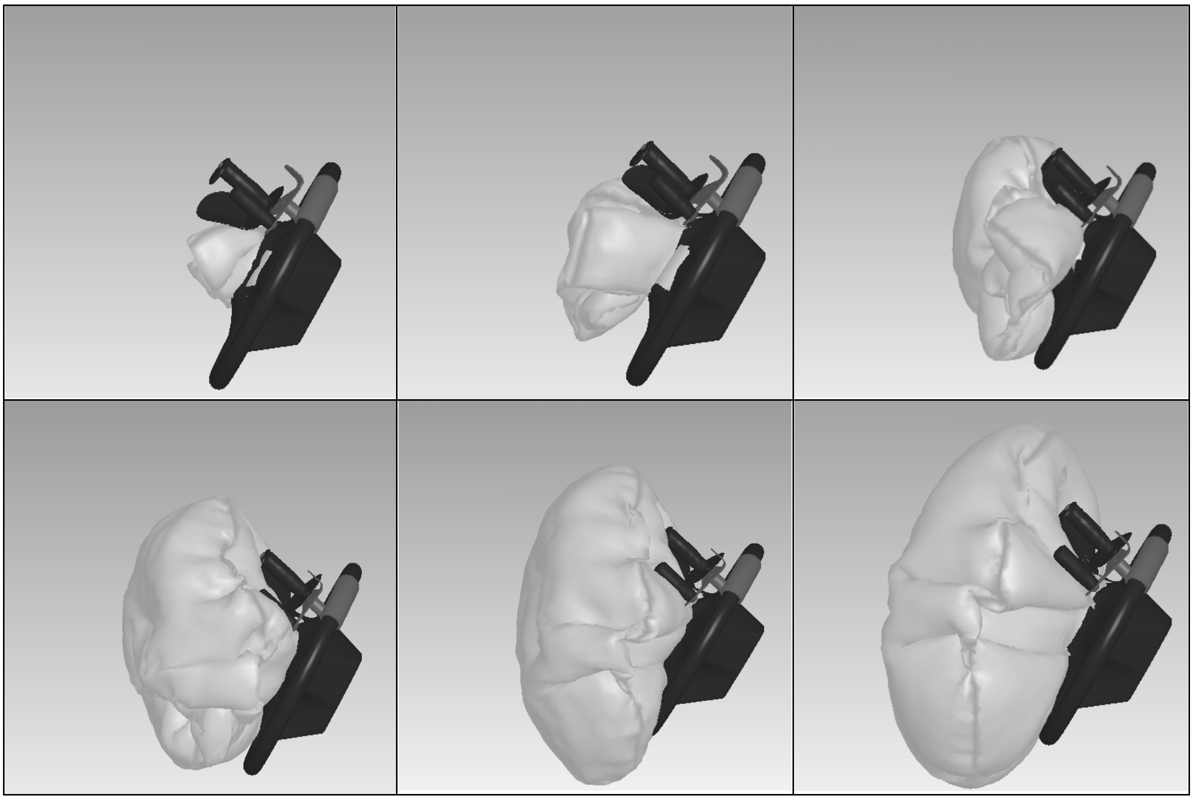

FIGURE 7. Example of an adapted steering wheel airbag explosion simulation.

Although we only analyzed the interaction between airbag and adaptation device, concerning the driving position, we considered the normal or standard driving position, in which the distance between driver and steering wheel (and therefore airbag) is the optimum position for correct functioning of the airbag. A disabled driver will often sit in a closer position to the steering wheel in order to better use the adaptations.

Table 1 shows the average distances values obtained according to the various fitting positions.

TABLE 1. Maximum and minimum distances are shown from the reference surface on the steering wheel to the outside edge of the airbag. Timings are also shown.

Type of adaptation	Minimum distance (mm)	Maximum distance (mm)	Timings (ms) Dist. min	Dist. max
Knob	10	33	8	14
Remote control knob	16	41	9	22
Forked knob	7	122	7	26
Double knob	3	112	6	24

5. CONCLUSIONS

We have studied various combinations of expansion and deployment of airbags and this has enabled us to obtain the time/pressure curve produced in the interior of the airbag. This curve offers a clear indication of the shape of the explosive opening of the airbag. Reliable models have been obtained for comparison with the actual results – and so enable an analysis of the level of passive safety available to physically handicapped individuals in the driving position.

The study suggests that the interference of the control adaptations in the area of airbag deployment significantly affects the positioning of the airbag following a collision. This means fitting such adaptations causes a notable decrease in the passive safety of disabled drivers. The forked knob and double knob are the adaptations that most intrude into the space occupied by a deployed airbag and so produce the worst positioning of the airbag.

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