PROTECTION METHODS AIMED AT LOWERING HEAD TO BONNET IMPACT INJURY LEVEL

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Abstract
Presently, the passenger vehicles have a compact assembled structure under the hood. Some rigid parts, like the suspension's upper restraint points and the breech are very close placed to the bonnet. Because of it, most of the times, there is not enough distortion space in event of a head-to-bonnet impact, thus leading to fatal injuries.
By using advanced impact sensors, bonnet lifting means, integrating bonnet distortion space and other design modifications, the automotive industry could help towards substantially lowering head injury level.

1. GENERAL INFORMATION

In most countries, including those of the European Union, pedestrians and other road users form a significant proportion of all road user casualties.
In the European Union around 7000 pedestrians are killed every year (EEVC, 1998; ETSC, 1999). This accounts for around 20% of all traffic fatalities. The situation is different for Romania, however, where 1103 out of 2238 fatalities are reported to be pedestrians, which translates into 49% of all traffic fatalities.

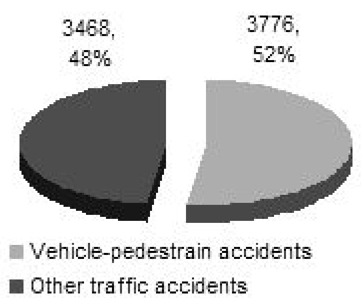


Fig. 1. Vehicle to pedestrian impacts rate, Romania, 2002

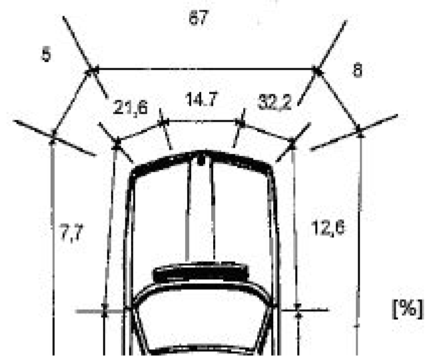


Fig. 2. Pedestrian impact regions

When considering the entire casualty range of traffic accidents, more than 52% of them are vehicle to pedestrian accidents, as shown in figure 1.
About 67% of the involved pedestrians are impacted by the vehicle front-end, while about 80% of the vehicle-pedestrian impacts take place at speeds below 40km/h.
Most casualties come from 8-14 and over 65 age ranges, thus being children or senior citizens.
Figure 3 below illustrates a collision between vehicle and pedestrian. In this figure a collision with a child is depicted as a special variant case.

It is obvious, that this situation is very dangerous for the pedestrian. The whole body of the pedestrian can be endangered, namely the legs, the torso, the thorax and the head.

Today's cars are very densely packed under the bonnet. Certain stiff parts, such as the spring tower and the top of the engine, are very close to the bonnet. There is often not enough space for bonnet deformation by an impacting head. The consequence is often a severe or fatal head injury.

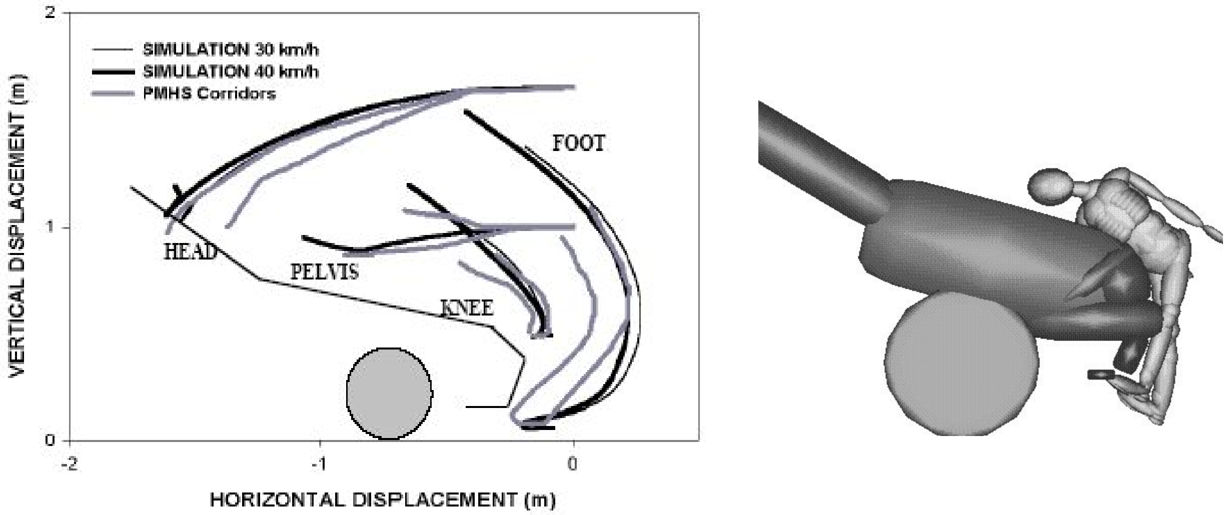


Fig. 3. Vehicle to pedestrian impact. Left – adult, right, child. [source TNO Automotive]

Modern cars have very stiff components underneath the bonnet, sometimes with gaps less than 20 mm. Therefore the deformation space is too small to allow for the necessary energy absorption in a head impact. Theoretically around 55 mm of stopping distance is needed at an impact speed of 40 km/h to be able to keep the HIC value below 1000 for an adult headform. Zellmer and Glaeser (1994) performed headform-to-bonnet impact tests where they showed that bonnets which allowed for 70 mm of deflection or more generally produced HIC values below 1000 for the adult head (Figure 4). The child headform needed only around 50 mm.

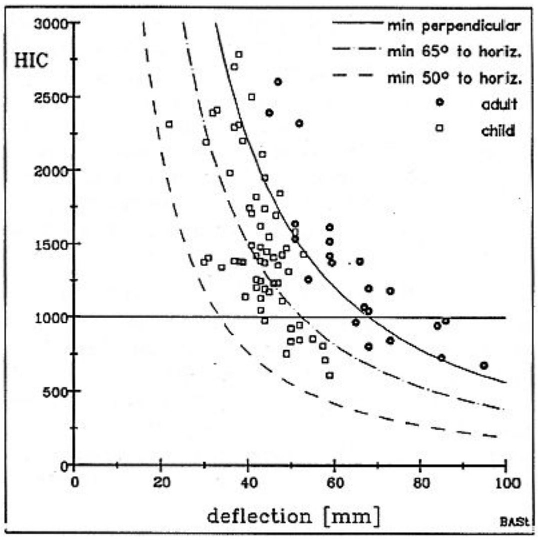


Fig. 4. Zellmer and Glaeser bonnet headform tests, 40 km/h impact speed, BASt, Germany [1]

The Zellmer and Glaeser tests were done in ideal conditions with enough free space. They don't take into account the vehicle technical boundary conditions like hinges and locks.

Research has shown that measures to improve car design, to mitigate pedestrian injuries in collisions, can be very effective in reducing the number of fatalities and serious injuries.

Therefore the European Commission supported the development of advanced protection systems suitable for supporting certain standards of pedestrian protection.

Protection methods divide into pure-passive/ crash-active and active methods:

Examples of pure-passive methods are:

- Soft front structures and modifications of these structures;
- Enhancement of driver's view;

Examples of crash-active methods are:

- Lifting hood;
- Exterior airbags (e. g. Windshield Airbag);

Examples of active methods are:

- Brake-Assistant;
- Electronic Stability Program (ESP);

2. SOFT FRONT STRUCTURES AND MODIFICATIONS OF THESE STRUCTURES

As can be seen below, two types of modifications can be made:

- structural stiffness modifications to lower impact injury level;
- part-to-hood height modifications in order to ensure enough crush space;

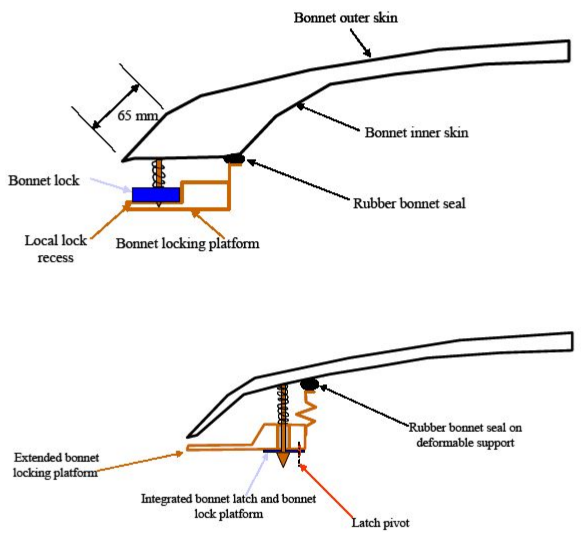


Fig. 5. Bonnet reinforcement. Existing and changes proposed.[5]

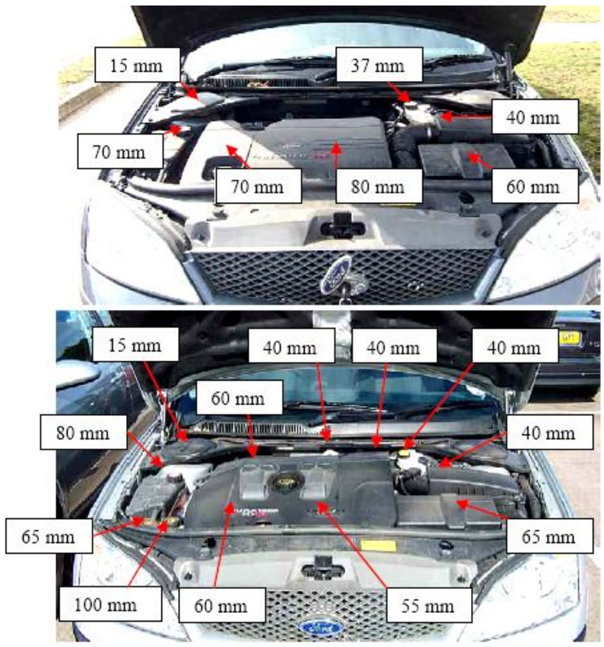


Fig. 6. Ford Focus crush depth measurements. Petrol and diesel variants. [5]

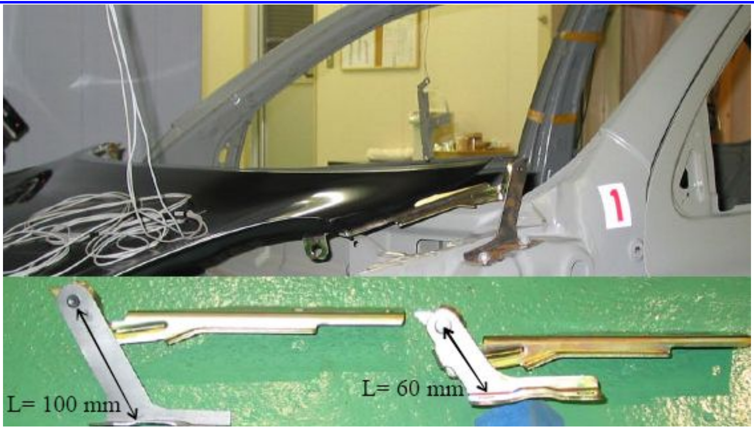
While further densing up the structure under the hood, in order to increase the crash volume – hood-to-structure distance, is not an easy to follow solution, lifting the bonnet in case of impact or generally is more likely to be developed as height increase solution. The Japanese Automotive Research Institute JARI came up with a modified hinge which increased the crush space with about 30mm (see figure 7.).

3. HOOD LIFTING METHOD

Deployable bonnet system requires two key components:

- sensors, in order to detect possible impact events and the actual impact;
- actuators, to ensure rapid and controlled lift of the bonnet

Contact sensors in the front of the bumper are implemented in order to feed information about the impact towards the ECU, which then uses a safety algorithm to decide whether or not to deploy the bonnet.



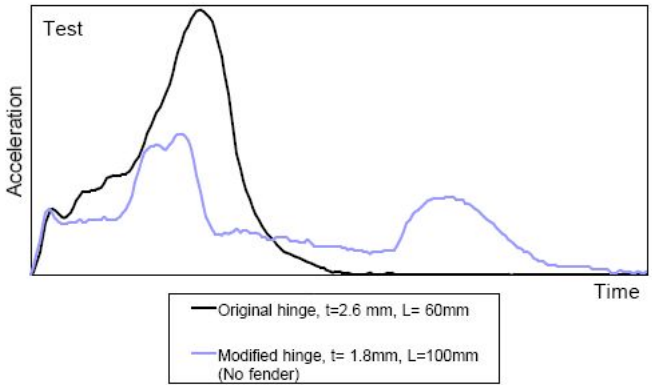


Fig. 7. Test with original hinge (60mm)versus modified hinge (100mm)

The sensor is able to discriminate between different impacting objects. Figure 8 shows the tests performed at 25 km/h. A clear difference can be seen between the sensor output signals for two different impacting objects, a leg and a pole. The worst case to discriminate would be between the lowest pole reading and the highest leg reading. This ratio for the Autoliv 25 km/h test was 2.6.

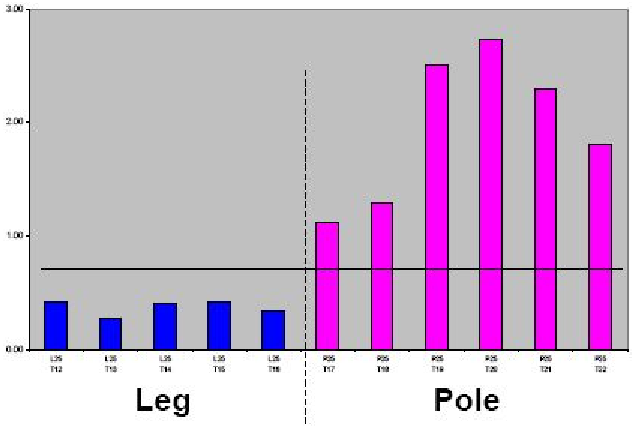


Fig. 8. Sensor tests at 25 km/h with different impacting objects at different impact positions on the bumper

At 30 km/h, the bumper beam structure started to yield in some tests. Also in two 25 km/h tests permanent deformation of the bumper beam occurred. In those tests the sensor output was much greater than in the tests, in which the bumper beam remained intact. Therefore the ratio of pole to legform signals was much greater than 2, ranging from 4 up to 18.

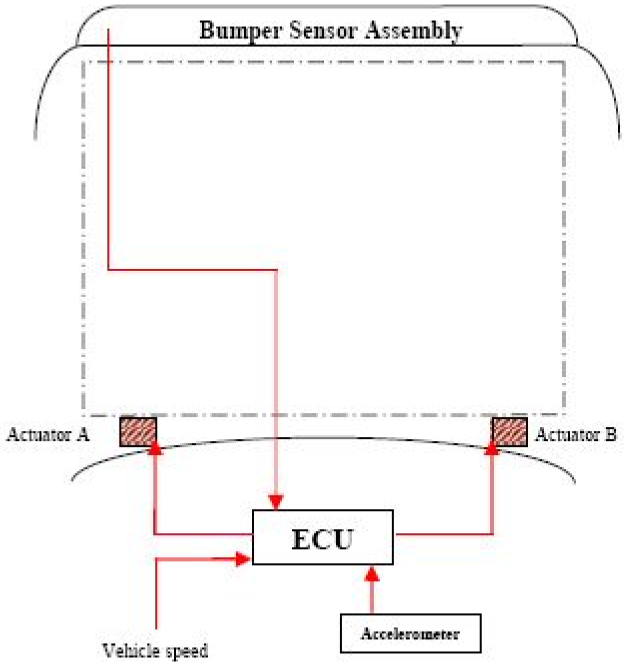


Fig. 8. ECU integrated ESP system

An integrated pedestrian protection system has to be controlled by an ECU (Electronic Control Unit). The sensor-ECU-actuator link is exposed in figure 8.

The actuation part is an interesting challenge, because the key is not only to get a rapid and reliable response, but also to do it at the lowest possible cost. High cost has ruled out the electric motor an an actuator. Thus, TRW has chosen to research the following actuator types:

- Spring-based systems. TRW has found a cost effective spring based reversible system to carry out bonnet deployment.
- Pyrotechnics. These are very cost efficient but can be used only once, after which the vehicle would need garage maintenance

Autoliv Research and Chalmers University of Technology have developed such a system in order to decrease the severity of head-to-bonnet impacts. The system is activated at the impact by a sensor located in the bumper, at speeds above 20 km/h. The sensor is able to discriminate objects with a different geometry (another car versus a leg), as well as with a different stiffness (a pole versus a leg). Two actuators lift the rear part of the bonnet approximately 100 mm. The actuators were tuned to have lifted the bonnet at 60 – 70 milliseconds after the leg-to-bumper impact, but before the head impact. The actuators/ lifting elements were also tuned to stay up during the upper torso impact, but still be energy absorbing to keep the head loading down if the head impact is on top of the lifting elements.

Modern cars have very stiff parts underneath the bonnet with gaps even less than 20 mm. Therefore, the deformation distance is too small to allow for the necessary energy absorption.

The hood lifting system is a possibility to increase the space between engine and hood, if this is necessary because of the package.

To quantify the load on the head the HIC (Head Injury Criterion) value was introduced. HIC is an internationally accepted, acceleration-based measurement for the violence against the head in a crash.

$$HIC = (t_2 - t_1)\left[\frac{\int_{t_1}^{t_2} A_R \, dt}{(t_2 - t_1)}\right]^{2.5} \qquad [1.1]$$

Where:
A_R = Resultant acceleration
t2-t1 = time interval

HIC-values under 1000 imply that the risk for life-threatening head injuries is 15 percent or less. But the curve rises sharply; at 2000 HIC the risk is almost 90 percent.

The lifting hood method was shown to perform well for an adult. The sensor system proved to be able to differentiate between impacts with a legform and a pole. The active bonnet proved to be able to be activated quick enough and to keep headform HIC values

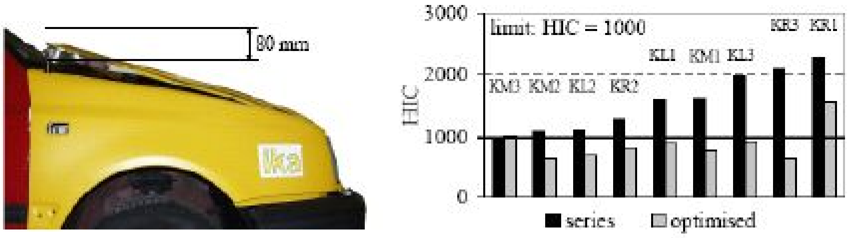


Fig. 9. Child Head Protection Improvement

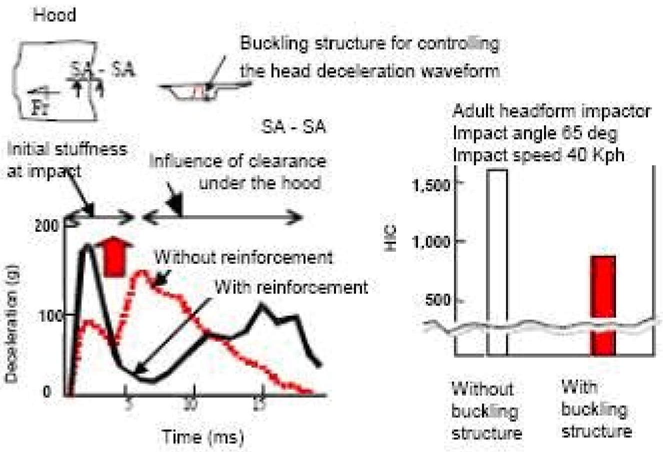


Fig. 10. Bonnet structural modification effect

below 800 at all impact points at 40 km/h. Also at an impact speed of 50 km/h, a large reduction of the HIC value was achieved, down to around 1200.

The effect induced by the child headform protection improvements can be seen in figure 9, while the overall bonnet structural modification effect, too, shows a significant reduction on AIS and HIC scale.

4. EXTERNAL AIRBAGS

The external airbag is one in a range of new and powerful intelligent systems that could soon find their way into many passenger cars, as automobile manufacturers together with technical researchers and government agencies focus their collective energy and resources on technologies that promote greater driving safety.

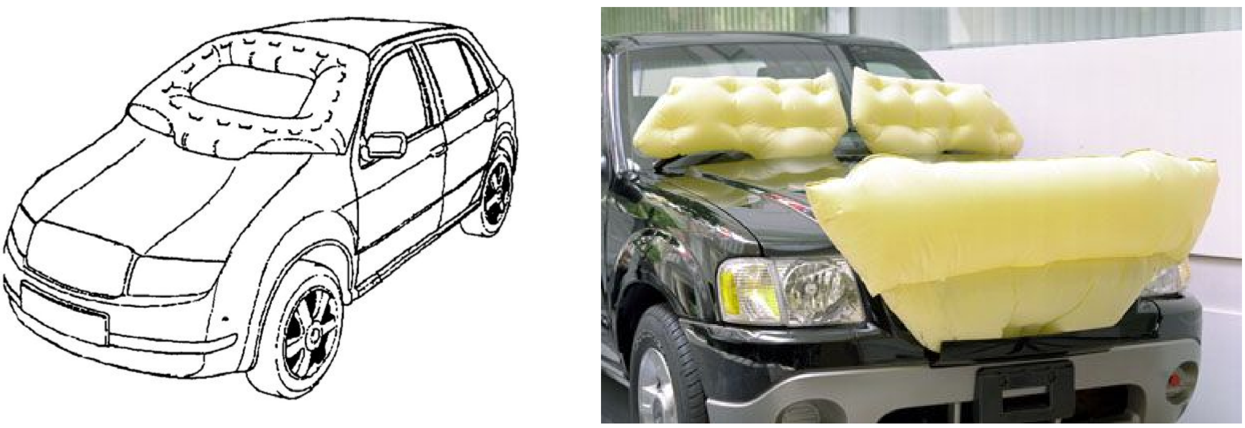


Fig. 11. Windshield Airbag proposal. Includes A-Pillar airbags (left) and actual implementation (right)

Autoliv tested a windscreen airbag in a mixed experiment with the active hood. The external airbag and its effect can be seen in the figure bellow.

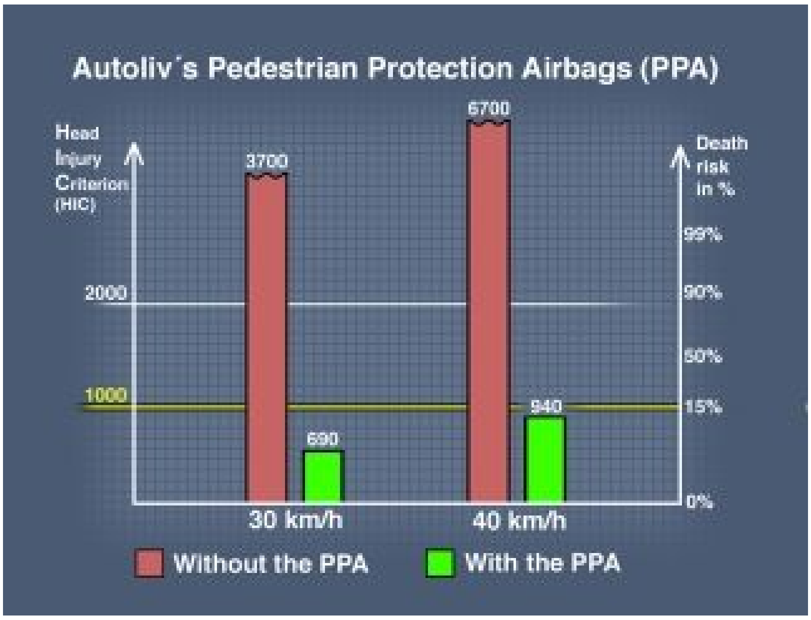


Fig. 12. Pedestrian Protection Airbag

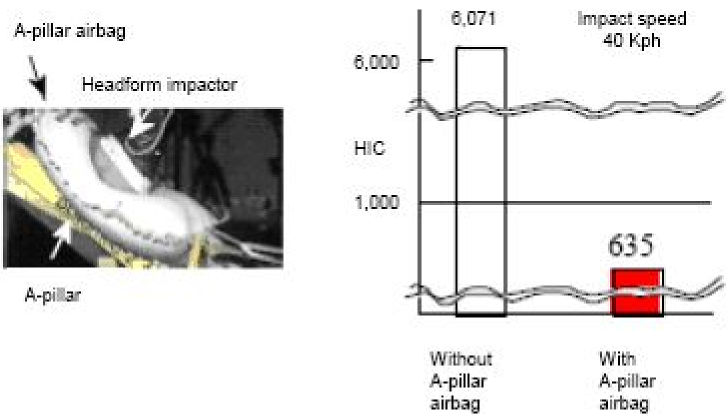


Fig. 13. A-Pillar Airbag and effect

Other type of external airbag has been tested by Autoliv. The A-Pillar airbag effect shows a great reduction for the HIC scale (Figure 13). The Bumper airbag effect also shows an improvement regarding impact velocities.

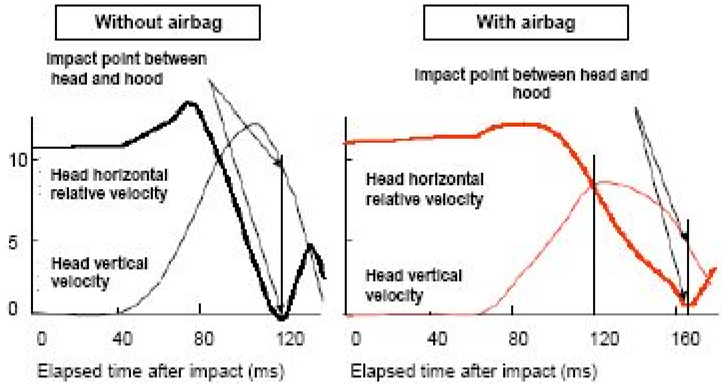


Fig. 14. Bumper Airbag Effect

5. CONCLUSIONS

- Front structures modifications are in order for generating more crash volume and to modify stiffness values for all designed cars willing to pass the EU 2003/102/EC Directive.
- The active hood system has proven to be efficient in lowering AIS and HIC values, but the actuator's cost efficiency problem remains for low-end consumer cars.
- External airbags proposals and implementations have not yet reached maturity and standardization, thus very few car models are expected to integrate such safety measures in the near future.

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