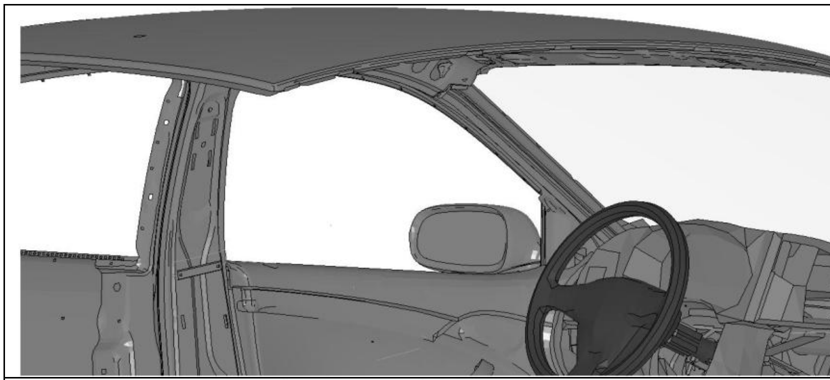
Expandable A-Pillar Phase II



Project within Crash Safety (active and passive)

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Content

FFI in short

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1. Executive summary

There are contradictory requirements on the A-pillar of a modern passenger vehicle. The A-pillar needs to be strong to help withstand the forces like in a roll over and help maintain the occupant cell integrity in roll over and high speed offset frontal crashes. The A-pillar needs to be slim for good visibility and the A-pillar needs to be light to contribute to lower fuel consumption.

An A-pillar which is folded during normal operation and in a crash is expanded by high pressure gas, resulting in a significant increase in cross section and strength may combine the contradictory requirements. Such an A-pillar was developed in this project. The A-pillar was initially folded and sealed. The goal was to develop an A-pillar that was lighter, have a smaller obscuration angle and have the same level of safety for the occupant as a state of the art A-pillar. Expansion and pressurisation of the folded sealed A-pillar was accomplished by generating a high internal pressure using pyrotechnics which is a cost- and weight efficient way to generate high pressures.

The development was carried out by combining full vehicle crash simulations with mechanical tests. The load cases used in the development of the inflatable A-pillar was an offset deformable barrier crash in 64 km/h and a roof crush test according to FMVSS 216. The inflatable A-pillar concept was subsequently built and mechanically tested. The A-pillar model was validated by means of the mechanical tests. Generally there was a good agreement between the predicted A-pillar shape and the shape of the expanded mechanical A-pillar.

The developed expandable A-pillar combined the goals with high strength, smaller cross section and lower mass. The developed A-pillar reduced the obscuration angle by 25% and the mass by 8% (excluding brackets and gasgenerator) relative to a state of the art A-pillar while maintaining the level of safety for the occupant.

2.

3. Background

Rollover accidents critically injure and kill thousands of people every year through head and neck injuries [1]. Structurally weak roofs can be a primary cause of serious head, face and neck injuries to occupants who are not ejected in vehicle rollovers. Due to the fact that belt is used by most passenger vehicle occupants today the number of ejected occupants is low and therefore the occupants are vulnerable to injury within the vehicle. In a rollover accident the roof can crush in a number of different ways depending on the design of the roof and the vehicle trajectory (Figure 1). The most severe breakdown is a complete pillar collapse.

Figure 1. Various Types of Roof Crush

A weak roof can collapse and buckle in this type of crash, imposing forces on and occupant's head that are substantially greater than those that would result from the vehicle drop itself. The association between vehicle roof strength and occupant injury risk in rollover crashes appears robust across different vehicle groups and across roof strength-to-weight ratios measured at 5 inches (12.7 cm) (SWR_5). The roof strength-to-ratios varies typically from just more than 1.5 to just less than 4.0 [2]. If roofs were to increase in strength by one SWR_5, a 20-25% percent reduction in risk of serious injury in rollovers would be expected.

In the modified standard for roof strength, FMVSS 216, it states that a roof must withstand pressure equals to 3.5 times the vehicle weight and the roof may not contact the head or neck of a seated 50%-ile Hybrid III dummy [3]. NHTSA estimates that the new rule prevent 44 deaths a year [4]. The rule applies to all vehicles with a Gross Vehicle Weight of 2722 kg (6 000lbs).

Not only roll over accidents exposes the A-pillar to extreme loading conditions [5]. Frontal collisions and in particular frontal offset collisions expose the A-pillar to extreme loading conditions [6] (Figure 2). Consider a transverse vertical plane in line with the dash. The resulting cross-section might include the A-pillars, side doors, door sills and floor. About 50% of the vehicle's weight will usually be rearward of this plane. The compression forces arising in these components due to a 40g deceleration are therefore equivalent to about 20 times the weight of the vehicle. This places a severe demand on the structure.

Figure 2. Offset Collisions Exposes the A-pillar to Extreme Loading Conditions [6] and [7]

To obtain a strong roof the most important vehicle component is the A-pillar (Figure 3). However, there are conflicting requirements on the A-pillar of a passenger vehicle. For occupant protection the A-pillar needs to be stiff and strong to withstand the load in a roll over or a fontal impact at high impact velocity. The A-pillar obscures the vision for the driver. The typical obscuration angle for a modern passenger vehicle is in the range of 8 – 12 degrees. Therefore, for the vehicle driver to have good visibility the A-pillar needs to be slim (have a small cross section). In addition for the vehicle to have low fuel consumption the A-pillar needs to have low mass. The ideal A-pillar is one that is slim during normal driving and when added stiffness and strength is needed such as in a roll over accident the A-pillar expands and increases the cross section and crush resistance.

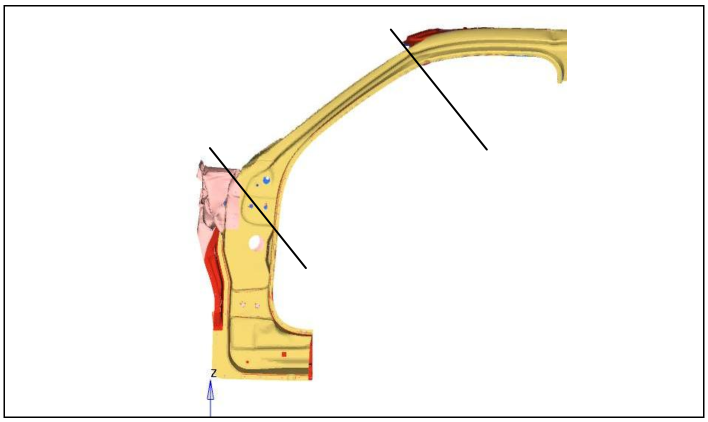

Figure 3 A-pillar

In an A-pillar with an expandable cross section the conflicting requirements can be combined in on component. During normal driving the cross section of the component is folded which provides the driver with good visibility. In an accident the A-pillar expands which results in a significant increase in the cross section and the greater cross section increases the strength of the A-pillar. Expansion of sealed folded steel components such as A-pillars can be accomplished by a generating a high internal pressure. A cost- and weight-efficient way to generate over pressure is by pyrotechnics (gasgenerators).

4. Objective

The aim of the project was by means of full vehicle simulations and component testing evaluate the potential of an expandable A-pillar to combine the contradictory requirements of small obscuration angle, low mass and high strength and, when expanded, have the same deformation force as a state of the art A-pillar. The project goals were to reduce obscuration angle by 20% and reduce the mass of the A-pillar by 30% with maintained level of safety for the vehicle occupants.

5. Project realization

The project was carried out by combining mathematical simulation with mechanical component tests. Mathematical models with varying complexity were used. Initially the development of the expandable A-pillar was carried out using a sub-model in which the boundary conditions were extracted from a full vehicle simulation. When an A-pillar design was developed that had the potential to fulfil the goals the evaluation continued in a full vehicle mathematical model.

For gasgenerator development mathematical component models of the A-Pillar were used. Various gasgenerators were evaluated with the model and the gasgenerators that fully expanded the A-Pillar were ordered and used in mechanical evaluation of the A-Pillar. The most promising A-Pillar design was built and expanded

The mechanical A-Pillars were also integrated into a body in white structure and expansion tests were carried out. In addition crash tests with the body in white structures with expanded A-Pillars were carried out.

6. Results and deliverables

The expandable A-pillar design that fulfilled the goals was 680 mm long, the shape was somewhat curved, the wall thickness was 1.5 mm and the material used was steel grade CR4 (Figure 4).

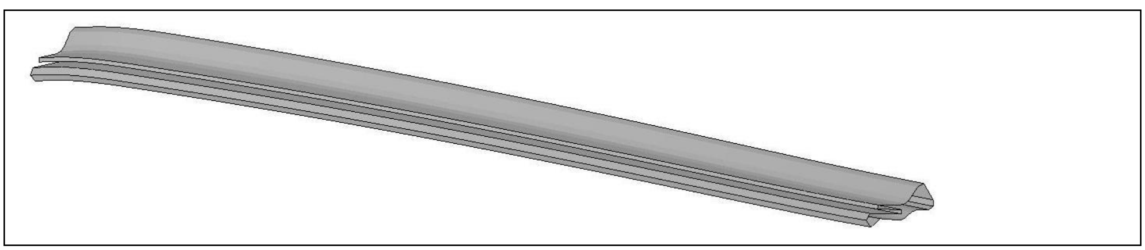

Figure 4. Inflatable A-pillar

The mass of the A-pillar was reduced by 8% and the obscuration angle was reduced by 18% relative to the state of the art A-pillar. The obscuration angle was for the left hand side A-pillar reduced from 12.3 to 8.9 (28%) and for the right hand side from 9.3 to 7.2 degrees (23%) (

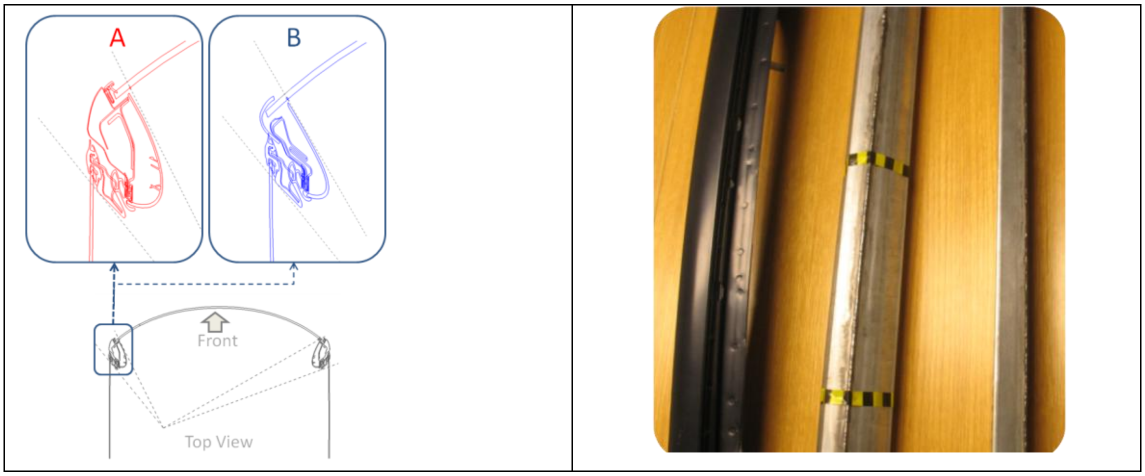

Figure 5. Obscuration angle for State of the Art (A) and folded expandable A-pillar (B) (left picture), and Reference, Expanded and Folded A-pillar (right picture)

The cross section when folded was 23 mm and expanded 62 mm (Figure 6). The expansion of the A-pillar increased the cross section of the initially folded structure increasing the moment of inertia of the A-pillar. The principal moment of inertia increased from 147 000 mm^4 when folded to 198 000 mm^4 when expanded. The moment of inertia for the reference A-pillar was 260 000 mm^4.

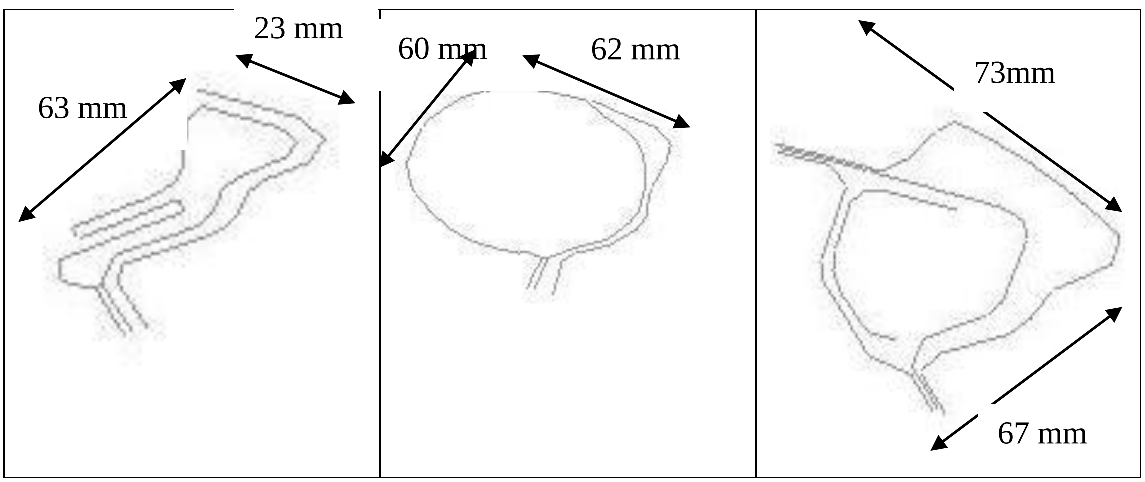

Figure 6. Cross Section of Folded and Expanded Inflatable A-pillar and Reference A-pillar

In the 40% offset deformable barrier crash configuration the deformation mode of the reference A-pillar and the expanded inflatable A-pillar was similar (Figure 7). The weakest point on the A-pillar was located at approximately the same location. For the unexpanded A-pillar the deformation mode was different. The weakest point was lower than for the expanded A-pillar.

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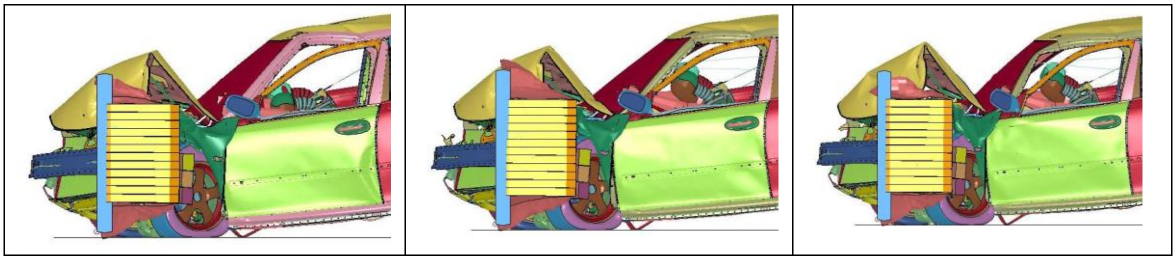


Figure 7. Reference, Expanded and Unexpanded A-pillar at 120 ms in Offset Deformable Barrier Crash Configuration at 64 km/h (40 mph)

The predicted A-pillar displacement was very similar for the reference A-pillar and the expanded A-pillar (Table 1). For the high and mid A-pillar displacement locations the expanded A-pillar resulted in displacement which were somewhat greater than for the reference A-pillar, while for the low door opening the deformation was somewhat smaller for the expanded A-pillar. For the unexpanded A-pillar the high A-pillar displacement distance was negative (increasing) while the mid and low A-pillar displacement was increased significantly. For the expanded and pressurised A-pillar the reduction in A-pillar displacement ranged from 17 to 14% relative to the Reference.

Table 1 A-pillar Displacemenents. The reference A-pillar displacement was normalised to 1. The Unexpanded, Expanded and Expanded Pressurised displacements are relative to the reference A-Pillar displacemens

	Unexpanded Reduction	**Expanded Reduction**	**Expanded Pressurised Reduction**
A High	-169%	-8%	17%
B Mid	-95%	-3%	15%
C Low	-51%	13%	13%

For the A-pillar cross section force at the cantrail the greatest peak force was for the expanded and pressurised A-pillar (Figure 8). The cross section force for the expanded only and reference A-pillar was similar. However for the unexpanded inflatable A-pillar the cross section force was lower.

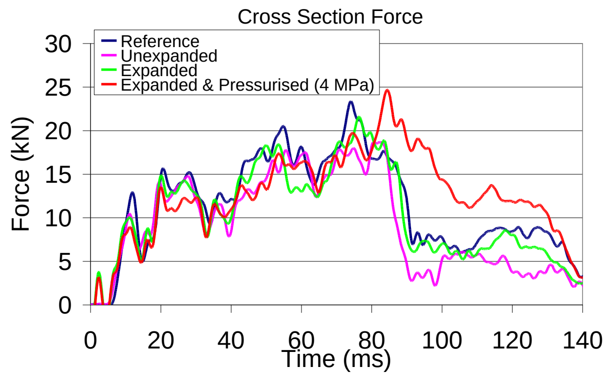


Figure 8. Cross Section Cant Rail Force in Offset Deformable Barrier Crash at 64 km/h (40 mph)

In the roof crush load case there were generally small deformations on the A-pillar (Figure 9). The weakest point was located at the same location in all three A-pillars.

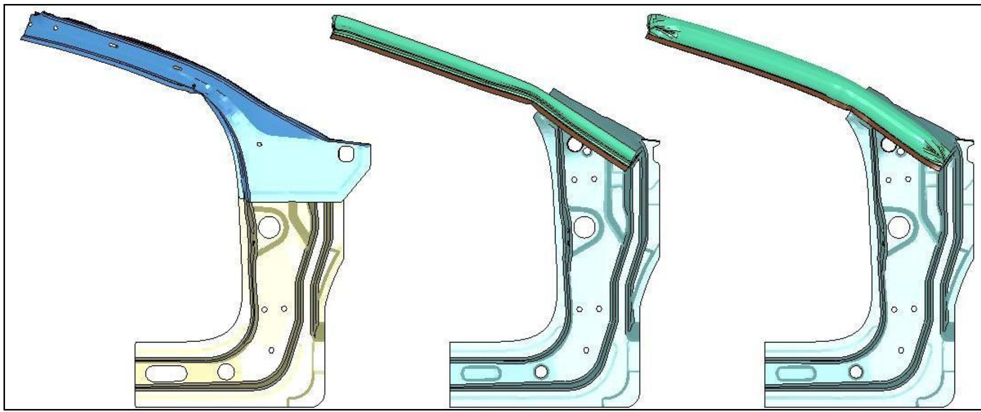


Figure 9. Reference A-pillar, Folded & Expanded A-pillar at 100 mm Roof Crush Displacement

There were no significant variation in the contact force between the vehicle and the rigid wall for the state of the art, for the unexpanded and the expanded A-pillar (Figure 10). However the contact force was somewhat higher for the reference A-pillar than for the expanded A-pillar and somewhat higher for the expanded A-pillar than for the unexpanded. A constant force level of 50 kN force was reached at 50 mm rigid wall displacement.

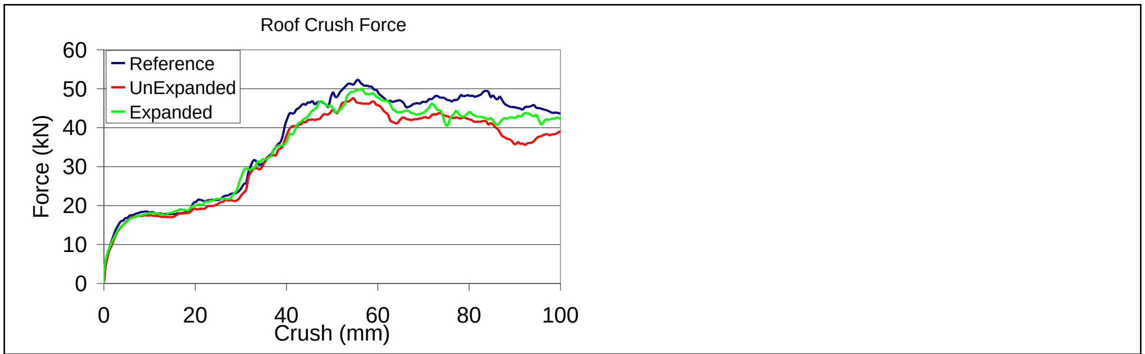


Figure 10. Force vs. Crush for Roof Crush Evaluation

Expansion evaluation of the mechanical A-pillar prototype was carried out (Figure 11). The prototype gasgenerator was inserted inside the A-pillar at the end and the A-pillar was expanded. The expansion of the A-pillar was very rapid. The structure was fully expanded after 15 ms.

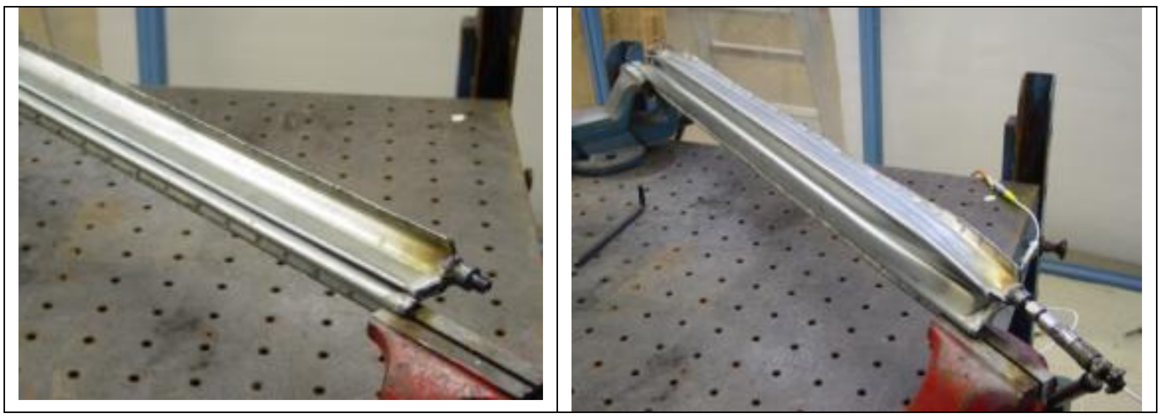
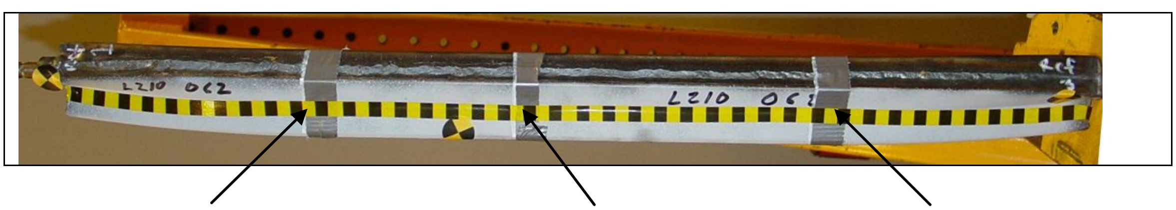


Figure 11. Folded and Expanded Mechanical Inflatable A-pillar Prototype

The shape of the mechanical A-pillar after expansion at ¼, ½ and ¾ along the length of the A-pillar was very similar to the predicted shape (Figure 12). All edges in the folded A-pillar were not completely pulled out by the pressure. The diameter of the expanded A-pillar was 63 mm and the moment of inertia was 135 000 mm^4.



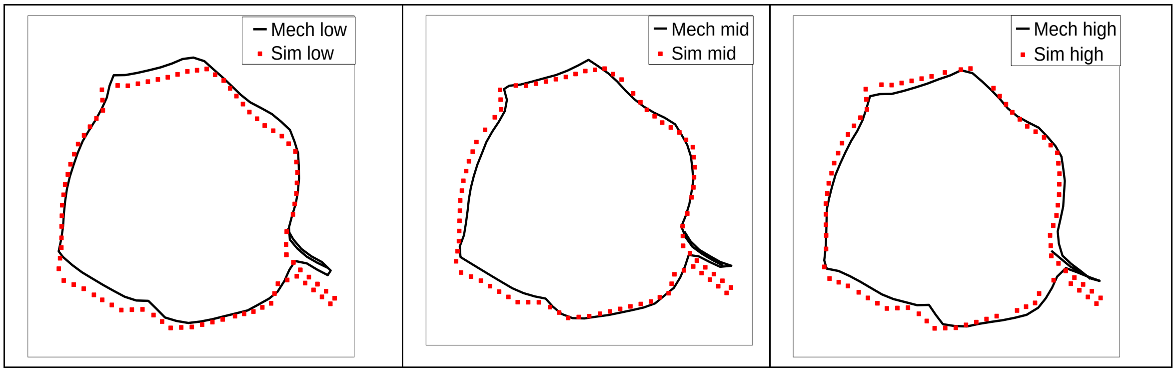


Figure 12. Mechanical and Mathematical Expanded A-pillar Cross Section at ¼, ½ and ¾ of the Length of the A-pillar

5.1 Delivery to FFI-goals

The project seeks to enhance the integrated safety of occupants and contribute to the "vision zero" ("Vision Zero"). The goal is to improve vision for the driver which increases the active safety, and increase the strength of the vehicle structure which increases the passive safety.

To reduce vehicle weight components reduces the mass of the entire vehicle. This helps to reduce fuel consumption and emissions from the vehicle

The project has also resulted in a patent application, SP70064EP, ”Elongated Structure for a Vehicle”.

Manufacturing of the expandable structures is a complex procedure. There are companies in Sweden that are experts in metal forming. Mass production of an expandable structure can therefore be a new product for such a company.

7. Dissemination and publications

6.1 Knowledge and results dissemination

With the development of electric vehicles there is a potential for new technologies in the area of light weight design. Combining the expandable structure technology with a light weight material such as aluminum can increase the strength to weight ratio of the vehicle components significantly and make the technology very attractive.

6.2 Publications

Following publications have been published or submitted:

Pipkorn, B., Lundström, J., (2010) “Expandable A-pillar for Improved Occupant Safety and Vision”, ICRAH2010, Washington D.C.

Pipkorn, B., Lundström , J., Ericsson, M., (2011) ” Safety and Vision Improvements by Expandable A-Pillars”, 22nd International Conference on Enhanced Safety of Vehicles, Washington D.C.

Pipkorn, B., Lundström, J., Ericsson, M., (2011) “Improved Car Occupant Safety by Expandable A-pillars” International Journal of Crashworthiness” (Submitted)

8. Conclusions and future research

Conclusion

- The expandable A-pillar improved the obscuration angle, was lighter than- and as strong as a state of the art A-pillar.
- Obscuration angle was reduced by 20%
- Mass of the A-pillar was reduced by 10%

Future Research

Due to the fact that the study was limited to the structural A-pillar additional evaluations of the influence of the expandable A-pillar on the interfaces such as trim panels, brackets, other joints etc need to be thoroughly performed. In addition to use the technology in a complete vehicle the integration of the expandable A-pillar has to be done with the initial design of the vehicle. Full vehicle evaluations have so far only been performed by simulations i.e. need also to be evaluated by complete vehicles and evaluation of the deployment timing etc needed in real-life crashes.

Combining the expandable structure technology with a light weight material such as aluminum or composites can result in additional weight benefits. However, additional research in the area is needed.

9. Participating parties and contact person

The participating parties were Autoliv Development and Saab Automobile. The contact person is Bengt Pipkorn, bengt.pipkorn@autoliv.com

10. References

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