New belt geometries in rear seat from a comfort, handling and safety perspective


Project within FFI's Traffic Safety Program

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

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1. Executive summary

This study presents a comprehensive research effort that combines expertise from industry and academia and uses various methodologies with applied research directed towards countermeasures.

Most advances of restraint systems have taken place in the front seat, including developments of airbags and seat belt technologies, such as pretensioners and load limiters. Some of these technologies are available in the rear seat, however to a more limited degree. Additionally, in order to advance the rear seat safety, pre-crash events need to be further explored and addressed.

The overall aim of the project was to evaluate different advanced seat belt concepts that can help maintain the rear seated occupant well restrained during a crash, including potential pre-crash maneuvers. Different aspects influencing the seat belt position/placement was to be evaluated; including attitude, handling and comfort as well as influence of various pre-crash scenarios, such as steering maneuvers, run-off road scenarios and braking.

The project was divided into two parts. The first part developed and evaluated two new belt geometry concepts (adding an extra belt to the 3-point belt) in terms of attitude, handling and comfort. The second part evaluated the pre-pretensioner influence on occupant kinematics together with a 3-point belt, during potential pre-crash events.

The results from the belt geometry concept studies revealed that children and adults generally showed positive attitudes towards the extra belts. The majority would like to have an extra belt in their family car and they considered the use of the extra belt just a matter of habit. It was shown that comfort experience had great influence on the preferred concept and the perception changed over time. Body shape and size affected the seat belt fit to a great extent, and consequently the comfort. When tried on, the new belt geometry concepts were often perceived better than the test subject expected and they experienced decreased discomfort the longer they were using it. These results show the importance of using various methods when evaluating new concepts, in order to get a more complete picture of the end-users experience and opinions.

In the second part of the project, evaluating the influence on occupant positioning using pre-pretensioners, a number of maneuvers, and complex events, such as run off road driving were tested. Using various sizes of crash test dummies, the pre-pretensioner helped reduce the excursion during evasive steering maneuvers and run-off-road driving by maintaining the shoulder belt position and thereby restraining the occupant prior a potential impact.

Overall, the project results provide insight into the importance and challenges of understanding potential pre-crash occupant positioning issues for the rear seated occupant, including initial belt-fit and the possible effect of pre-crash maneuvers. The

studies have resulted in comprehensive knowledge, including new methods to evaluate belt systems in terms of attitude, handling and comfort and crash safety. This input can be used by the industry to design future safety systems.

2. Background

Worldwide, road traffic was the second leading cause of death among 5-14 year olds in 2002 (WHO, 2004). In US, for every day in 2006, in average 5 children 14 years and younger were killed and 568 were injured in motor vehicle crashes (NHTSA, 2006). The majority of rear seat occupants are less than 13 years old (McCray et al., 2006). Most advances of restraint systems have taken place in the front seat, including developments of airbags and seat belt technologies, such as pretensioners and load limiters. Some of these technologies are available in the rear seat, however to a more limited degree.

The head is the most commonly injured body region for severe injuries regardless of restraint system and crash direction for children injured in motor vehicle crashes (Durbin et al. 2003, Howard et al. 2004, Arbogast et al. 2004). Bohman et al. (2010) found that pre-crash maneuvers may contribute to head injuries to restrained children in frontal impacts. Evasive steering maneuvers may cause the shoulder belt to slide off the shoulder resulting in excessive forward head excursion allowing head contact with the seat back in front of them. In a steering maneuver test (Bohman et al 2011) this hypothesis was confirmed, the shoulder belt moved out on the shoulder in various extent to short and tall children depending on their restraint system.

Although the vehicle 3-point seat belt has saved many lives over the years, improvements to the seat belt can most probably save even more lives, such as during steering maneuvers prior to a crash. However, changes to the seat belt have to be taken into account the comfort and handling of the seat belt, in order to maintain high acceptance and high usage. Addressing pre-crash maneuvers, various approaches can be used. In rally vehicles, 6-point belts are used to maintain the occupants well restrained, similar approach can be used in passenger cars. Another solution is to use pre-pretensioner, an electrical reversible retractor that can tighten the belt prior a potential pre-crash event and maintain the occupant better restrained during the whole event.

This project focuses rear seat occupant protection by exploring advanced seat belt concepts.

3. Objective

The overall aim of the project was to evaluate different seat belt concepts that can help maintain the rear seated occupant well restrained during a crash, including potential pre-crash maneuvers.

4. Project realization

This study presents a comprehensive research effort that combined expertise from industry and Department of Design and Human Factors at Chalmers in the joint effort to improve safety in order to reduce the number and severity of injuries rear seated occupants in passenger cars. The project was initially planned for 2011-2012, but was prolonged and was finished by the end of 2014.

The project was divided into two parts. The first part developed and evaluated two new belt geometry concepts (adding an extra belt to the 3-point belt, see Figure 1) in terms of attitude, handling and comfort. The second part evaluated the influence of pre-pretensioner during pre-crash events on occupant retainment. The project contains attitude studies, handling studies, real world driving studies, physical crash testing and crash simulations.

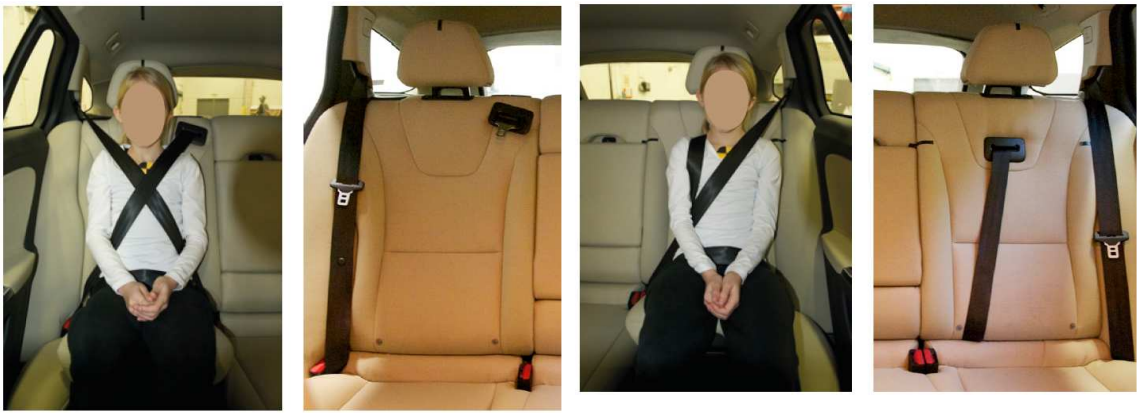

Figure 1 Two belt geometry concepts – adding a 2-point belt to the conventional 3-point belt.

5. Results and deliverables

Among the extensive results, the following is highlighted:

- Two complete concepts with new belt geometries was developed and evaluated in attitude, handling and comfort aspects.
  - The attitude study resulted in comprehensive understanding of how new belt concepts are received and what makes the user wanting and not wanting to use the belt system.
  - The handling study resulted in increased knowledge of how the first time user handles this type of belt systems.
  - The driving studies resulted in increased knowledge of how the user perceives the comfort of the systems during driving sessions.
  - The handling problems among the first time users were further evaluated in an in-depth study.

- Pre-pretensioner retention of child and adult crash dummies was evaluated for various pre-crash scenarios in an extensive test program.
- The studies have resulted in comprehensive knowledge, including new methods to evaluate belt systems in terms of attitude, handling and comfort and crash safety. This input can be used by the industry to design future safety systems.
- The project has resulted in academia results, such as several student project works, Master thesis (60 hp). There is ongoing work to publish results in scientific publications.

5.1 Delivery to FFI-goals

The project has provided several important results for safety in the rear seat of passenger cars, which is to date a less explored area as compared to the front seat. Acknowledging that there is a high representation of children and elderly among the rear seat passengers, the impact on overall safety benefits is important. Specifically towards the FFI-goals, the highlights are:

- Qualitative input to the design of future safety systems, which will improve the protection to the occupant and thereby contribute to fulfill Vison Zero as well as VINNOVA'S aim of reducing fatalities in motor vehicle crashes.
- The comprehensive work, including concept development and evaluation, contributes to the possibility of industrial development of new products.
- The project has contributed to improve the co-operation between university and industry as well as between industry partners.
- Additionally, the project has substantially contributed in developing the competence within child safety research, further strengthening the leading position and long heritage of Swedish car industry.
- The participating industrial partners, can in a competitive way, offer increased crash safety protection for rear seated occupants in pre-crash events prior impact. This unique competence contributes in maintaining and further strengthen the leading position of Swedish car industry in this area.
- The project contributes to maintain and further develop the competence in pre-crash safety, both within product and method development, feeding essential knowledge into future AD applications.
- The project has produced several internal reports, which will become public in peer-reviewed journals. Besides, several student project has been conducted, including a master thesis work.

6. Dissemination and publications

Throughout the project, the results have been shared within the project partners in addition to between the partners as well as with parallel relevant research projects. Externally, the project result dissemination has to some extent been performed during project duration and more is planned. Parts of the belt geometry concept studies were included in a Master thesis presented and published 2014. The comfort study of the geometry concept studies is accepted for publication in AAAM in 2015. Additionally, parts of the safety evaluation dynamic testing, including influence of the pre-pretensioner is planned to be published as a part of a PhD thesis during 2015-16. In addition to this at least one scientific publication is planned.

6.1 Knowledge and results dissemination

The studies have resulted in comprehensive knowledge, including new methods to evaluate belt systems in terms of attitude, handling and comfort and crash safety. This knowledge as well as the methods can be used by the industry to design future safety systems.

This project relates to several other research projects involving project members. The synergies with these projects include input to this project as well as a platform for realizing the result from this project and taking the next steps in potential implementation.

An obvious connection is to “Rear seat safety – focusing on occupants from 3 years to 5th percentile female in frontal to side impacts part II” (Dnr 2012-03668), where complementary research is ongoing in parallel, benefiting of and developing the child safety related aspects of project in this report. For the adult occupants, the work within Active Human Body Model for Virtual Occupant Response, Steps 2 and 3 (Dnr 2010-02860 and 2014- 0393) provide an important interaction and facilitator of the project results, although different focus on seating positions (rear vs front seat). As complementary research a master theses project is recently started, to further address how the pre-pretensioner can be used in pre-crash scenarios.

Addressing potential pre-crash events, the results of this project, including the methods developed, provide essential input and tools for projects within the area of collision mitigation technology, enabling evaluation of occupants influence in pre-crash maneuvers.

Beside future research in the area, the results from the project feed directly into vehicle design through the participating industrial partners.

6.2 Publications

Hansson I, **Analysis of evaluation methods for attitudes and comfort experience of new seat-belt concepts for the rear seat in cars**. Master Thesis, Chalmers University of Technology, CPL ID: 183964, 2014.

7. Conclusions and future research

This project has resulted in comprehensive knowledge of how new belt geometry concepts are perceived and what makes the user wanting or not wanting to use the belt system. Furthermore, the extensive safety testing in various pre-crash scenarios of concepts of pre-pretensioner, have resulted in valuable understanding that can be used in further product development.

Comprehensive knowledge has been gained during the development of the methods used to evaluate the attitude, handling and comfort of new belt concepts. The understanding of what results can be obtained depending on what evaluation method is used, can be applied into evaluation and development of other safety systems as well. Further research is encouraged in the area of method developments as well as further design development. Evaluation tools for pre-crash events needs further development, since current tools (physical and CAE tools) are designed for the crash event. A HBM model with active muscles needs to be developed in order to simulate pre-crash events in CAE models.

This project has shown that pre-crash events can influence rear seated occupants' position prior a potential crash. Using various sizes of crash test dummies, measures such as a pre-pretensioner helped reduce the excursion during evasive steering maneuvers and run-off-road driving by maintaining the shoulder belt position and thereby restraining the occupant prior a potential impact. Pre-crash events are important to address in order to enhance car safety and will be even more important in future traffic. Cars will include a higher degree of active safety systems, assisting the driver by braking and steering maneuvers. This will increase the number of potential pre-crash events, the occupants will be exposed to. The knowledge and methods designed and evaluated in this project will provide essential input to future developments in occupant protection. Some of the findings will be carried on in other research projects, however more research is needed to further explore all the different situations as well as improving occupant protection strategies and design enabling potential future industrialization.

8. Participating parties and contact person

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