Chest injury prediction in heavy vehicle collision tests

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2013-10-31
Project within Vehicle and Traffic Safety

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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.**

For more information: www.vinnova.se/ffi

1. Executive summary

The goal of the project was to develop and implement methods for improved chest injury prediction and improved measurement of chest deflection in crash test dummies when crash testing heavy commercial vehicles. Moreover, the goal was for the Ph.D. student to be able to finish his Ph.D.

The project has carried out the following.

- Sled testing and full-scale testing of trucks have been performed according to the test procedure developed in previous project (No. 2009-00079).
- Evaluation of results from sled test and full-scale crash tests with trucks. The results indicate that the measurement of the chest deflection from the RibEye™ equipment was slightly higher than the chest deflection measured by the potentiometer in the Hybrid III crash test dummy.
- Communication and implementation of the measurement procedure for internal product development.
- Continued doctoral studies to further develop and improve the chest injury criterion by; instrumentation of the Hybrid III crash test dummy, evaluation of injury risk when the chest is impacting the steering wheel, and tests and simulations for validation. However, the Ph.D. student has not been able to finish his Ph.D. due to delays and unexpected circumstances. Most of the material is available but there is no more time and resources in the project to be able to complete the final scientific articles as well as his thesis even though the project was extended on two occasions. The Ph.D. student has a vision to finish his Ph.D. on his own.
- The results are presented in two scientific journals (TIP 2013 & IJCrash 2013).
- The results have also been distributed internally and externally at SAFER seminars.

2. Background

Swedish-made heavy vehicles have a strong tradition of working with safety. Major investments have been made to improve the passive safety, including detailed safety targets and validating crash tests. Existing dummies are designed for the conditions and load cases which are most common in passenger cars. Thus, limitations occur when the dummies are applied for heavy commercial vehicles. One such limitation is the correct prediction of chest injuries in a frontal impact.

3. Objective

The goals of this project were to develop and implement methods for improved chest injury criteria and implement methods to better predict chest injury criteria. Additionally, to secure that the Ph.D. student could finish his Ph.D.

4. Project realization

The following activities have been performed in the project.

- Sled testing and full-scale testing in trucks have been performed according to the test procedure developed in previous project (No. 2009-00079).
- Evaluation of results from sled testing and full-scale crash tests with trucks.
- Communication and implementation of the measurement procedure for internal product development.
- Continued doctoral studies to further develop and improve the chest injury criteria by; instrumentation of the crash test dummy Hybrid III, evaluation of injury risk when the chest is impacting the steering wheel, and tests and simulations for validation.
- The results are presented in two scientific journals (TIP 2013 & IJCrash 2013) and spread internally at Volvo and externally at SAFER seminars.

5. Results and deliverables

- A Hybrid III dummy has been instrumented with RibEye™ equipment for non-contact measurement of chest deflection at several points on the crash test dummies' chest. This instrumentation has been evaluated in sled tests and full-scale crash tests with trucks. Proposed method, developed in the "*2009-00079 - Further development of passive safety test and measurement methods for heavy commercial vehicles*", has been used to measure the crash test dummies' chest deflection at the point of impact in these sled tests and full-scale tests and compared with measurement of chest deflection with the Hybrid III dummy potentiometer. The results indicate that the measurement of the chest deflection from the RibEye™ equipment was slightly higher than the chest deflection measured by the potentiometer in the Hybrid III crash test dummy.
- A scientific paper has been published and accepted by the "International Journal of Crashworthiness". This article analyses the Hybrid III chest deflection in frontal truck crash tests. The Hybrid III chest deflection, as measured by the potentiometer, is not always reliable for steering wheel to the chest contact in a crash test with a truck due to only one measurement point in the Hybrid III dummy. A more accurate chest deflection can be determined by combining

RibEye™ measurement with kinematics and correct impact point of the Hybrid III.

- A scientific paper has been published and has been accepted in "Traffic Injury Prevention". The goal of this article was to try to improve the quality of the chest injury risk during steering wheel contact for a Finite Element Hybrid III dummy in frontal truck crash tests. Correction factors were developed that can be used to correct the Hybrid III chest response.
- A study was conducted with the aim to evaluate the human thorax compared with THUMS in a range of simulated steering wheel impacts. The similarities in the relative differences between the results of THUMS and the human thorax were satisfactory. A complete manuscript is written and will be sent to a scientific journal after internal review.

5.1 Delivery to FFI-goals

The work has contributed to increased knowledge of how different parts of the passive safety systems contribute to the total safety level for the heavy commercial vehicle. This will be an important tool to reach the goals to perform relevant development activities and to strive for that new knowledge is developed and implemented and that existing knowledge is implemented in industrial applications.

The work is also aiming to develop knowledge and strategic tools that are needed to ensure that Swedish manufactured heavy commercial vehicles maintain the position as leading in safety, which is an important contribution to the goal to *contribute to a continued competitive Swedish vehicle industry.*

The work is also contributing to the goal to *strengthen the cooperation between vehicle industry, authorities, universities, and research institutes.* AB Volvo and Chalmers are both partners in the SAFER center. A significant part of the project has been performed in the SAFER environment at Lindholmen Science Park. By that, the project has benefited from the SAFER environment and from other SAFER related projects using similar tools, for instance human body models. The project also contributes to the SAFER environment and thereby also to the goal to *support research and innovation environments.*

Furthermore, the project has contributed to the Vehicle and Traffic Safety program goals by definition and validation of *evaluation methods for passive safety* and by research within *Biomechanics, human modeling and method development*. The results are relevant for industrial applications within heavy commercial vehicle transports.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The results have been presented internally at Volvo and externally at a number of SAFER seminars, and in two scientific journals, see "6.2 Publications" below (TIP IJCrash 2013 & 2013). The results will also be used for further communication of passive safety in the Volvo organization.

6.2 Publications

Holmqvist, K.; Thorn, S.; Rundberget, P.; Törnvall, F.; Svensson, M. Y. (2013) Heavy vehicle frontal sled crash test analysis – chest deflection response in the Hybrid III dummy, International Journal of Crashworthiness, 18:2, 126-138, DOI: 10.1080/13588265.2013.763611, 26 Jan 2013

Holmqvist, K.; Davidsson, J.; Mendoza-Vazquez, M.; Rundberget, P.; Svensson, M. Y.; Thorn, S.; Törnvall, F. (2013) Improving Hybrid III Injury Assessment in Steering Wheel Rim to Chest Impacts Using Responses from Finite Element Hybrid III and Human Body Model, Traffic Injury Prevention, DOI: 10.1080/15389588.2013.803083, 29 Jul 2013

7. Conclusions and future research

- The project results have given an increased competence and knowledge on how different parts of the passive safety systems contribute to the total safety level for the heavy commercial vehicle. This will be an important tool to be able to perform relevant development activities and to strive for that new knowledge is developed and implemented and that existing knowledge is implemented in industrial applications.
- However, the Ph.D. student has not been able to finish his Ph.D. due to delays and unexpected circumstances. Most of the material is available but there is no more time and resources in the project to be able to complete the final scientific articles as well as his thesis even though the project was extended on two occasions. The Ph.D. student has a vision to complete the doctoral degree during spring 2014, after completion of the project. Chalmers offers continued guidance to enable this.

8. Participating parties and contact person

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