

OCCUPANT PROTECTION IN FAR SIDE CRASHES

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ABSTRACT

Regulations and interventions to protect far side occupants in side impact crashes do not currently exist, even though these occupants account for up to 40% of harm in real world side impact crashes. To address this, a comprehensive international research program has been assembled involving many of the world's experts in side impact protection and biomechanics. Seven work-tasks are outlined for conducting this research, which is due to be completed by the end of 2007.

INTRODUCTION

Side impacts are frequent and extremely harmful crashes. The likelihood of being killed or seriously injured is very high in side impact crashes. Twenty five percent of vehicle casualties (28 percent of fatalities) occur from these crashes, accounting for roughly one-third of occupant Harm on our roads (Fildes, Lane, Lenard & Vulcan, 1994).

Current side impact regulations in Europe, the USA, Japan and Australia specify acceptable performance levels for a single crash configuration and impact speed for near side occupants. This is appropriate as near side crashes are extremely common and harmful to occupants involved in side impact collisions. Fildes, et al, 1994; Frampton, Brown, Thomas and Fay (1998); and Digges and Dalmotas (2001) all reported that near side occupants account for up to 70% of all side impact injuries. However, far side occupants are involved

in 30% of injuries and up to 40% of occupant Harm in real-world side impact crashes (Fildes, Gabler, Fitzharris. & Morris, 2000). This seating position is currently not addressed by existing vehicle safety initiatives around the world. It is critical therefore to address all side impact types and speeds in future designs and safety regulations.

The in-depth study findings reported by Fildes et al. (1994) showed that the frequency and rate of head injury was greater in far side than near side impacts with fewer chest and abdominal injuries. The head injuries resulted from contact with the far side door, the impacting vehicle or object or other occupants. Dalmotas (1983) reported earlier on injury mechanisms for occupants in real world crashes restrained in 3-point seat belts in side impacts in Canada. While they noted different mechanisms for near and far side occupants, they claimed that both would benefit from improvements in side door integrity and interior padding.

Kallieris and Schmidt (1990) conducted simulated far side impacts using cadavers seated in the rear seat with inboard-anchored shoulder belts. They reported no head injuries for far side occupants with these belt configurations compared with those of near side occupants and lower angular head/neck velocities and accelerations. However, most of the PMHS showed AIS1 injuries to the neck, which in the light of recent whiplash research corresponds to a high probability of disabling injury outcome (i.e. hemorrhages in the inter-vertebral discs).

There has been extensive work completed on near side impacts to define injury tolerance and biofidelity requirements (Cavanaugh Walilko, Malhotra, Zhu and King (1990a,b); and Pintar et al., 1997). In recent work, Pintar and his colleagues conducted 26-side impact sled tests with PMHS impacting a sidewall with a range of different surface conditions. They investigated a number of biomechanical responses and injury tolerances from these tests for occupants involved in near side crashes. Because injury criteria and biofidelity requirements for near side occupants are dependent on a direct impact to one whole side of the body, these results are not directly applicable to far side crashes. Additional far side impact tests are critical for understanding occupant kinematics, forces and accelerations for occupants involved in these kinds of real world crashes. Stolinski, Grzebieta and Fildes (1999) undertook a series of crash tests in Australia focussing on near and far side occupant outcomes. From far side HIII and US-SID full-scale crashes, they showed that deploying belt pretensioners could significantly reduce lateral excursion of the far side occupant and reduce lap belt loads. However, there is reason to question whether current side impact test dummies, designed for near side impacts can accurately reflect far side kinematics and injuries.

Previous far side research undertaken in Australia (Fildes, Sparke, et al 2002) identified a number of strengths and weaknesses with existing side impact test dummies for far side occupant protection. They concluded there was scope for improving dummy design in far side crash testing, and that a comprehensive research program into far side crashes, occupant injuries and countermeasures was warranted to address this severe trauma.

THE RESEARCH PROGRAM

To address these concerns, an international collaborative research program into increased protection for far side occupants in a crash was developed and commissioned at the start of 2004. The research involves a consortium of universities, auto manufacturers, and part suppliers as shown in Table 1.

The study was funded through a number of contributions from government and industry sponsors, comprising the Australian Research Council in Australia, Ford USA through GWU, Holden Australia, and Autoliv in Sweden. Considerable in-kind contributions were also provided from these sponsors as well as all the participants.

Table 1: Consortium Members

Institution	Participants
Monash University Accident Research Centre, Australia	B.Fildes, A. Linder, C.Douglas
George Washington University (NCAC), Virginia	K.Digges, R. Morgan, B. Alonso
Virginia Tech (CIB)	S. Duma, E. Kennedy, J. Stitzel
Virginia Tech (Mech. Eng.)	H.C. Gabler
Medical College of Wisconsin, Wisconsin.	F. Pintar, N. Yoganandan, B. Stemper
William Lehman Trauma Center, Miami	J. Augenstein
Wayne State University, Detroit	King Yang
Holden Australia	L. Sparke, S. Smith
Dept. Transport & Regional Services, Australia	C. Newland
Human Impact Engineering Sydney, Australia	T. Gibson
Autoliv AB	O. Bostrom, R. Judd
Ford USA	S. Rouhana

Research Objectives

There were three objectives associated with this research program:

- To obtain a more detailed understanding of far side crashes, injuries and injury mechanisms;
- To develop suitable test procedures and injury criteria; and
- The identification of a range of generic far side injury countermeasures to address this trauma.

In addressing far side occupant injuries, it was obvious from previous testing that the appropriate strategy would be to attempt to restrain the occupant in the seat to prevent contact with the struck side of the vehicle. Current restraint designs fail as the sash portion of the 3-point belt offers little restraint to movement away from the D-ring in a side impact. Fildes et al (2003) showed that a supplementary belt on the inside while offering a degree of restraint in this direction, also posed a potential problem of neck loading from the belt and potential problems for the carotid artery. Hence, there was also a need to examine this issue during the research program.

RESEARCH DESIGN

Seven research tasks were prescribed to address these objectives.

- Task 1- to obtain a more detailed understanding of far-side injuries and Harm in real-world crashes
- Task 2 - to undertake a comprehensive laboratory biomechanical test program using PMHS (cadavers) specimens
- Task 3 – to identify injury criteria and risk functions for neck injury
- Task 4 – to develop a suitable crash test program and suitable injury criteria
- Task 5 – to revisit the suitability of current side impact test dummies in this crash mode;
- Task 6 – to develop suitable computer models for generating far side occupant kinematics and injury parameters; and
- Task 7 – to identify a range of generic countermeasure options for mitigating injuries and Harm.

Research participants were assigned to each task and a work task leader took responsibility for overseeing the research, achieving the prescribed deliverables and outcomes and reporting on progress and any problems encountered. Each of the work tasks is described in more detail below.

Task 1 – Problem Identification

Two sub-tasks were identified for this research.

Initially, an examination was to be conducted from in-depth data in the USA and Australia of the level of Harm to far side occupants in side impact crashes by body region, injury source, crash direction, crash severity, intrusion extent, crash partner, occupant characteristics, and injury lesions. This would be used to focus the research program on major injury and Harm issues, as well as gaining a more detailed understanding of these crashes for addressing countermeasure strategies.

Towards the conclusion of the program, additional Harm analyses would be conducted to illustrate the potential Harm benefits of generic counter-measure strategies to reduce far side injuries.

Task 2 - Biomechanical Test Program

The biomechanical test program is designed to provide a range of human-like kinematics and injury responses under controlled conditions to use for comparing with test dummy responses as well as in developing computer models to simulate occupants in far side crashes. The priority crash types, impact speeds and restraint conditions identified in Task 1 would form the basis for conducting these tests.

Pre-modeling of dummy/cadaver performance using existing computer models of side impact

dummies was to be undertaken prior to these tests to minimize any potential problems or difficulties and ensure a satisfactory outcome

Follow-up PMHS tests at the conclusion of the research may be required as final validation of the countermeasure strategies.

Task 3 - Soft Tissue Injury of the Neck

This task has a number of sub-tasks associated with it. At the outset, a literature review will help identify current knowledge and best practice in neck injury causation and computer modeling with particular attention to carotid arteries.

Following this, a series of tests of neck soft tissue injuries will be conducted to determine constitutive properties and failure conditions. With the assistance of specimen testing to be conducted at MCW, a computer model of the carotid artery will then be developed and validated against biomechanical test data and if possible, real world crash data.

Finally, the model will be exercised to determine injury criteria, injury risk functions, and propose surrogate injury measurements for use on dummy outcomes to gauge the potential for serious neck injuries associated with any restraint solutions.

Task 4 - Test and Injury Criteria

As there are no agreed far side test or injury criteria, the fourth task is aimed at addressing these issues (Gibson et al, 2001).

Through a review of existing literature and the injury and Harm analysis in Task 1, preliminary test criteria will be specified for improved far side impact protection. In addition, acceptable injury criteria for use in far side testing will be arrived at predominantly from current biomechanical tolerance knowledge and additional analyses of existing biomechanical test data where available.

Throughout the research program, these will continue to be evaluated for their suitability for providing adequate protection for these occupants and if required modified in the light of more recent evidence. The findings at the end of the research program will be provided to auto manufacturers and governments around the world to encourage them to give greater attention to preventing these injuries.

Task 5 - Far Side Test Dummies

Previous work by Fildes, Sparke, Bostrom, Pintar, Yoganandan and Morris (2002) and Bostrom and Haland (2002) showed that existing side impact test dummies did not produce accurate occupant kinematics in a far side test. While a modified

BioSID fitted with a new design spring spine was found to be an improvement, it was solely a research instrument and had no role to play in regulation. Furthermore, the WorldSID test dummy included in this test program failed because of a problem between the dummy and the restraint.

The WorldSID appeared to have the potential for simulating far side occupant movements in a far side crash because it contains a more human-like spine. It has been developed by an ISO WorldSID Task Group in anticipation that it may be the appropriate test device for use as a side impact regulation. Hence, further testing of this dummy (now modified to overcome the restraint problem) would be undertaken in this research program.

From these tests, it should be possible to determine its suitability and the need for any modifications in this crash mode. It is planned to conduct a series of tests to validate the dummy responses against cadaver and injury outcomes (5 or 6 restraint combinations expected) and identify areas requiring further attention.

If found to be suitable, WorldSID will be used to conduct any additional tests required for far side model development and countermeasure evaluation.

Task 6 - Computer Model Development

Biomechanical and physical tests are limited by the time required to conduct these and their associated costs. Given recent developments in sophisticated computer models of occupants, the next task will be to develop such a human model for use in this test program and beyond.

The model will be developed from the biomechanical and test data collected during the program as well as in consultation with model developers around the world. A PhD scholarship has been provided by the Australian Research Council for a student to develop such a model at Monash University as part of his or her research study program.

The model development program will contain a number of associated activities. Initially, existing models of vehicles and dummies will be used to study intrusion, crash pulse, and kinematics in far side crashes. Subsequently, an improved human model will be developed using FEM technology and validated against test and real-world crash data.

It is expected that the model will be useful for examining a range of different crash types, impact angles and crash severities and also hopefully for different sexes and sizes of occupants in single and two-occupant interactions. The model will also

eventually be used to predict injury reduction of generic countermeasures in real world crashes for Harm benefits analysis.

Task 7 - Countermeasure Development

The final work task in this study is aimed at providing a range of suitable in-vehicle solutions and strategies to improve protection for far side occupants in a side impact crash. Generic in-vehicle countermeasures will be identified, tested and evaluated for their likely benefits and any associated disbenefits. It is expected that a range of potential generic far side protection strategies and countermeasures will be identified to encourage manufacturers to include these in future car models.

The countermeasures will be subject to rigorous testing both with the computer and physical models to illustrate their effects. These will be in terms of their likely kinematics and injury assessment benefits. In addition, Harm analyses will also be conducted to demonstrate potential benefits and costs for implementing fleet-wide. Optimum solutions and/or countermeasure packages will also be identified to help guide manufacturers and regulators in future initiatives.

EXPECTED PRODUCTS

The sponsors require that the outcomes of the research be made freely available for all to use as required. Hence, a number of products (deliverables) are expected from this research activity, as listed below.

- A paper on the frequency and severity of casualties in far and nearside crashes for restrained occupants in both the USA and Australia is to be presented at the ESV 2005 international conference.
- The results of the comprehensive test program using PMHS will be available on request to technicians for use in helping to further far side occupant protection.
- The identification of a suitable far side test dummy with appropriate kinematics, and injury response is expected for the far side environment (Max Harm and 75% of MAIS 3+ Injuries).
- Suitable injury criteria and injury risk functions for soft tissue neck injury will be published and a recommended test program and injury criteria will be available for use by governments and industry engineers.

- An FEM human computer model will be developed and validated for use in countermeasure determination and evaluation.
- Generic countermeasure strategies will be established to reduce head, neck, chest, abdomen and pelvic injuries in these crashes
- Harm benefits analysis of alternative generic countermeasures will be conducted.

RESEARCH TIMETABLE

A preliminary timetable for the research was established at the commencement of the research program, as detailed below.

Year 1 – To conduct various reviews, undertaken data analyses and priorities, and commence biomechanical testing.

Year 2 – To continue the laboratory test program, initiate dummy development and test procedures, and establish first estimates of injury criteria and assessment functions.

Year 3 – To commence computer modelling of various crash configurations and develop generic countermeasures to address these.

Year 4 – To conduct benefit-cost analyses of countermeasure options, complete final validation testing of these and write reports and papers.

PROGRESS SO FAR

Good progress has been made during the first year of the program. A Harm analysis of NASS crashes in the US and similar crash data at MUARC in Australia has been carried out revealing some interesting and unexpected results. A paper on these findings and areas of similarity and difference between these two data sets is to be presented in the side impact session of this conference. These findings are useful in helping to identify priority crash and occupant issues for research to follow.

Details for the biomechanical test program have been worked through following the Harm analysis. Focus for the PMHS testing will be on relevant injuries and seat areas most likely to be amenable to intervention in the conduct of this research. Testing facilities have been agreed upon and developed and it is expected that testing will commence at the Medical College of Wisconsin early in 2005.

A comprehensive literature review of neck trauma, especially that involving the carotid artery, and suitable modelling techniques has been conducted and will be ready for publication soon. In addition, researchers at Virginia Tech's Center for Injury Biomechanics have commenced modelling these

injuries using biomechanical results from sub-system tests. Early results appear promising and subsequent research is focussed on improving these models for later inclusion into the far side occupant protection program.

Research at George Washington University has focussed initially on pre-modelling of occupant kinematics in a far side crash using a range of existing dummy models to provide guidance for the biomechanical test program. In addition, a literature review of injury assessment functions and other relevant data is currently underway to help address the issue of suitable injury and test criteria for improved protection of far side occupants.

Efforts are also underway to construct comparative tests of side impact dummies to show whether any of the existing side impact test dummies are capable of simulating real world occupant kinematics and injuries in a far side crash configuration.

A student has been recruited into a PhD research program at MUARC in Australia to help develop a suitable far side human model. Four working group meetings were held during 2004 and the early part of 2005 to review research efforts and prescribe directions for future research. In addition, briefing sessions and early finding from this research have been presented to the IHRA Side Impact committee for feeding into their research program as well. The enthusiasm and support among the researchers involved in this program is especially noteworthy and there is high expectation that the outcomes and deliverables specified for the research will be achieved, leading to significant improvement in far side occupant protection in the years ahead.

CONCLUSIONS

The research commenced in January 2004 and a number of key research components are already well underway. Preliminary findings in the area of priority crash configurations, injuries and injury mechanisms have already been identified.

It is expected that through a comprehensive test schedule, this research will lead to a better understanding of occupant biomechanics and injury mechanisms during far-side collisions. Current dummy bio-fidelity can then be assessed and improved, appropriate far-side test measures developed, and recommendation for regulations made. It is anticipated that application of these test procedures will allow the development of innovative and world-leading far-side countermeasures that will ultimately improve vehicle occupant safety.

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