Abstract Booklet

Oral Presentations and Written Papers

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on the Enhanced Safety of Vehicles

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20th ESV Conference Theme and Technical Session Topics

Conference Theme: "Innovations for Safety: Opportunities and Challenges"

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Structural Integrity and Restraint Performance

Chairperson: **Stephen Ridella, USA** | ***Co-Chair:*** **Philippe Petit, France**

State-of-the-art in occupant protection through structural integrity and restraint performance is undergoing changes as structural characteristics and material changes occur. Additionally, the demands from restraints such as seat belts and air bags will change as technologies change and opportunities become available to tailor performance of restraints to meet the needs of various crash types and severities, and different vehicle occupants such as the elderly and children. Technical papers are invited in this session on the developments for improving effectiveness of seat belts, frontal and side air bags, side curtain air bags, adaptive belts and crash energy management for enhancing safety.

Compatibility in Frontal/Side Collisions

Chairperson: **Pierre Castaing, France** | ***Co-Chair:*** **Eberhard Faerber, Germany**

Two of the most predominant crash types that cause fatalities and injuries are frontal and side crashes. Much improvement in crash protection in frontal and side crashes has resulted from the design changes that have happened over the last two decades, especially in reducing fatal injuries. Changes in vehicle fleet characteristics have also created a new problem with respect to incompatibility of vehicles involved in multi-vehicle crashes. The problems involved in frontal crashes and side crashes of incompatible vehicles are distinctly different. There is considerable amount of research underway worldwide, to develop suitable metrics to assure structural engagement, for appropriate energy management and to develop suitable countermeasures including the use of advanced technologies to improve crash safety in frontal and side crashes. Papers are invited to discuss the various strategies that are being pursued globally in this session.

Active/Passive Safety: Applying Integrated Solutions Along the Crash Timeline

Chairperson: **John Hinch, USA** | ***Co-Chair:*** **Anders Lie, Sweden**

Over the last three decades, considerable amount of effort has been devoted to the protection of occupants during crashes. However, vehicle technologies that are evolving provide the opportunity to address safety continuously from crash prevention to crash severity reduction, crash protection and post-crash safety in an integrated fashion. Many new technologies are already on the road or are on the verge of introduction into vehicles. The use of these advanced technologies can help with new and innovative solutions to both current and emerging safety problems. They can supplement the traditional approaches related to crash avoidance, reduction of crash severity, occupant protection, post-crash safety and structural integrity of motor vehicles as integrated solutions. This session is intended to discuss papers related to research being carried out on this subject around the globe in research institutions, the governmental organizations, the suppliers and original equipment manufacturers

Vehicle Handling, Stability and Control Systems and Rollover Prevention

Chairperson: **Thomas Breitling, Germany** | ***Co-Chair:*** **Catherine Lovell, U.K**

Vehicle handling, stability and control research activities are an integral part of crash avoidance research. Vehicle designs that help to keep vehicles stable in their response characteristics avoid many of the safety problems related to skidding and loss of control. Many new technologies such as electronic stability control, roll stability control, advanced braking systems, traction control and such other technologies are gaining popularity. Developments in these technologies are bound to increase safety by preventing crashes that occur due to loss of control. This session invites papers on the above subjects to discuss the progress being made in active safety research.

Theme: "Innovations for Safety: Opportunities and Challenges"

Biomechanics: Injury Criteria and Test Procedures

***Chairperson:* Jean-Pierre Verriest, France | *Co-Chair:* Suzanne Tylko, Canada**

To motivate effectively and efficiently the incorporation of appropriate safety measures to address the multitude of automotive crash scenarios requires ever more diverse and robust injury criteria and test procedures. To advance the discussion on these necessary capabilities, this technical session aims to address and discuss (1) the development and application of analytical and experimental techniques to understand better the basic impact injury process, (2) analytical techniques that enhance the identification of mechanical responses that are determinants of the injury outcome, and/or (3) processes that enhance the interpretation and injury predictive accuracy of dummy responses.

Advanced Technologies: Human Performance

***Chairperson:* Peter Burns, Canada | *Co-Chair:* Kaneo Hiramatsu, Japan**

Keeping abreast of advanced technologies used in crash prevention, understanding their suitability for safety applications and their effectiveness involves their evaluation. This would include a comparison of the different technologies aimed at mitigating the same safety problems as well as their impact on driving performance, their unintended consequences, and driver workload issues. Additionally, devices that are brought into vehicles and their effect when used in combination with other in-vehicle devices would have to be thoroughly investigated. The human factors issues are of paramount importance as many different technologies are introduced into vehicles. This is particularly important when they are employed as driver assistance products to determine their effectiveness and customer acceptance. Further, systems that are also intended for driver behavior modification, improve driver alertness or enhance driving capacity requires extensive research using test track experiments, driving simulators and on the road driving. Papers are invited in this session covering this broad area of research on all of the above topics.

Developments in Side and Frontal Impact Protection

***Chairperson:* Bernie Frost, U.K | *Co-Chair:* Claudio Lomonaco, Italy**

Side impact protection has been a top crash safety priority in many regions of the world for more than a decade. The changing fleet characteristics and the advent of new technologies in vehicles necessitate a discussion of the latest research findings in this area. Presentations will include various aspects of side impact protection, including safety countermeasures, test devices and procedures for their evaluation, and consumer rating program for side impact protection.

Rear Impact Injury Prevention

***Chairperson:* Anders Lie, Sweden | *Co-Chair:* Lex van Rooij, The Netherlands**

Rear impacts, though common, rarely cause fatalities and serious injuries. However, they result in whiplash injuries that are common. Many researchers are pursuing this problem, investigating cause of whiplash injuries and developing countermeasures that could prevent such injuries. Further, suitable test devices (dummies, barriers, etc.) and injury criteria are also under development. Many new technologies for rear crash prevention are also being developed. This session invites papers on these subjects as they apply to rear crash safety.

Improved Safety for Pedestrians and other Vulnerable Road Users

***Chairperson:* Yoshiyuki Mizuno, Japan | *Co-Chair:* Ekkehard Brühning, Germany**

Pedestrian protection using autonomous vehicle based solutions has been the focus of research worldwide for many years. Much progress has been made in this area. The primary vehicle oriented countermeasures have centered on improving frontal structure of passenger vehicles to mitigate head and lower extremity injuries. However, pedestrian safety continues to be a serious problem in many countries. In many areas, in addition to vehicle-based solutions, infrastructure related

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solutions are also being explored. Advanced technology systems using radar, vision concepts and other types of sensors have been examined to identify pedestrians at intersections and to potentially provide warnings to drivers. The safety of two-and three-wheeled vehicles is also of particular interest in certain jurisdictions of the world. Technical papers on research related to these subjects and potential solutions are invited for this session.

Biomechanics: Tools Development

***Chairperson:* Jac Wismans, The Netherlands | *Co-Chair:* Craig Newland, Australia**

The many human surrogates developed over the last two decades and that are currently in use globally may need modifications to address the changes in injury patterns that emerge as new technologies are introduced into vehicles. Technical papers are invited to discuss the new tools that are available or are under development to address future safety needs for testing and vehicle design and development. Additionally, papers related to the need for global dummy development, virtual testing and other similar topics would also be welcome at this session.

Motorcycle Safety

***Chairperson:* Claudio Lomonaco, Italy | *Co-Chair:* Younghan Youn, Republic of Korea**

Motorcycle crashes are a cause of serious concern globally. In the United States alcohol use and speeding are cited as major contributing factors in crashes. Non-use of helmets is another concern. Many of these same problems exist in various other regions as well. Motorcycle rider education and licensing, reducing the number of impaired motorcyclists, increasing motorists' awareness of motorcycles and increased helmet use are appropriate means to improve motorcycle safety. Technical papers are invited on these subjects for this session. Any potentially new technologies that address any aspect of motorcycle safety are also invited for this session.

Advances in Child Occupant Protection/Restraint Systems

Chairperson: Craig Newland, Australia | Co-Chair: Hideki Yonezawa, Japan

Over the past two decades great strides have been made in motor vehicle safety. However, children under 10 years of age still receive serious and fatal injuries in crashes. In 2004, 1,241 children under 10 years of age were killed and 139,000 were injured in motor vehicle crashes in the United States. The problems other countries face in child safety are also significant. There are many causes for the unabated safety problem; inappropriate use of child restraints; ill-fitting lap and lap shoulder belts; and premature graduation from child restraints to vehicle safety belts are all possible causes of this continuing safety problem. Further, the range of child restraint systems (CRS) that are available and the suitability of conventional seat belts to secure the child restraints correctly to avoid misuse would greatly enhance child safety in motor vehicle crashes. Many countries are actively engaged in conducting tests of various CRS for frontal and side crash protection. Others are involved in developing universal CRS and ISOFIX. Technical papers describing the advances in child occupant protection and restraint systems, protection of children in various crash modes, and discussion of the types of injuries that are commonly found are invited for this session.

Advances in Truck and Bus Safety

***Chairperson:* Andrzej Szosland, Poland | *Co-Chair:* Mátyás Matolcsy, Hungary**

Safety technologies for trucks and buses are topics that have received immense attention in past ESV conferences. This ESV conference will continue to focus on those technologies, and also explore research in the human response area. With increasing attention on driver performance what are the safety technologies that can assist drivers of large vehicles in a pre-crash environment to lesson or prevent a crash scenario?

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Technical Session: Structural Integrity And Restraint Performance

Oral Presentations | Tuesday, June 19, 2007 | 8:30a.m.-1:00p.m.

Chairperson: Stephen Ridella, USA | Track A | Salle Rhône 3
Co-Chairperson: Philippe Petit, France

Paper No. 07-0060-O
Modeling And Simulation Of A Van For Side Impact Sensing Tests
Chin-Hsu Lin, *General Motors, United States*

Abstract:
The use of math-based tools has reduced the need for hardware prototyping and testing, which in turn reduces a vehicle's development time and cost. However, there are still many tasks in the vehicle development process that math-based tools cannot do well. Of these, the task of calibrating a side airbag sensing system is a major task that has not been addressed. To obtain the required acceleration signals for sensing calibration, expensive prototype vehicles have been routinely crashed for vehicle development. A math-based side sensing calibration capability could significantly reduce prototyping and testing costs, as well as shorten the vehicle development time. There have been a few papers published for the frontal sensing impact simulations but none for the side impact sensing impact simulation. The major difference between the frontal impact and the side impact is that the latter generally requires a much earlier airbag deployment time, which, in turn, demands an even higher degree of model fidelity to ensure timely deployment.

An extensive study on using non-linear finite element analyses to aid in calibrating a thorax or roof rail curtain airbag sensing system is presented. Modeling techniques and guidelines that are crucial for using a single vehicle model to simulate a suite of side crash test conditions and lessons learned from previously investigated frontal sensing finite element analyses were adopted. Techniques that are unique to the side impact simulations were identified and incorporated in a chosen van model. The van model was then used to simulate a set of no-deployment and deployment side impact calibration events. Immunity tests, however, are not part of the study in this paper. The simulation results were compared with available test data, and side impact sensing algorithms were used to determine the airbag deployment time. Airbag deployment times from the simulations are comparable to the test and it is strongly suggested from this study that a high fidelity vehicle model with a FEA-compatible sensing algorithm can greatly improve sensing simulation capability for side impacts.

Paper No. 07-0335-O
Stochastic Analysis Of Vehicle Models For Sensitivity Analysis And Optimization
Massimiliano Avalle, Giovanni Belingardi, Andrea Ibba, *Politecnico di Torino, Italy*
Kambiz Kayvantash, Franck Delcroix, *Altair Development, France*

Technical Session: Structural Integrity And Restraint Performance

Abstract:
Within the 5th Framework Programme EU project APROSYS, the Sub-project 7 is fully devoted to virtual testing. The aim is to improve the quality of the crash simulation in order to be able to come to rating and qualification by virtual analysis.
One of the main issues lies in the evaluation of scatter sources and the consequences of scatter on the results of the analysis. Therefore, great effort was devoted in the project to identify sources of dispersions, and their relevance.
To evaluate the influence of scatter on crash responses a series of stochastic models has been developed. Within the APROSYS project a series of generic car models was developed to perform this task. Generic car models are virtual vehicles, derived from the geometry, layout, and characteristics of the best-in-class models currently available on the market according to EuroNCAP ratings, generated to have commonly shared models to work out towards improvement of crash simulations.
In this work the stochastic model developed by using one of these generic car model, called GCM4, a multi-purpose vehicle, has been used. The stochastic model was generated by considering the stochastic variation of some parameters. In particular, the steel sheet properties were used as stochastic variables (input). Moreover, to evaluate the structural influence on the passenger behavior, a simpler stochastic passenger compartment model was developed.
The simulation runs were managed by a specific tool, called ADVISER, developed within the APROSYS project and its predecessor ADVANCE. The results were analysed by means of the post-processor included in the same ADVISER tool.
The results give further insight in the problem of the improvement of simulations for passive safety applications.

Paper No. 07-0236-O

Injuries In Rollovers By Crash Severity

Kennerly H. Digges,*The George Washington University*
Ana Maria Eigen, *National Highway Traffic Safety Administration, United States*

Abstract:
Earlier studies by the authors have examined factors that contribute to rollover crash severity. These factors include: (1) belt use, (2) the number of quarter-turns aggregated according to number of vehicle inversions, and (3) the damage severity from planar impacts with fixed and non-fixed objects that occur before or during the rollover. Further research indicated that rollovers with severe damage from planar impacts should be analyzed separately from other rollovers since the injury rates for these crashes is 2 to 3 times greater than equivalent crashes with less severe damage.

This paper separates rollovers into two categories, based on the presence or absence of severe damage from a planar crash. The research then examines the distribution of MAIS 3+ injuries and harm by body region and contact for belted and unbelted adult occupants in each rollover category. The rollover categories are further examined by ejection status, roll direction and number of vehicle inversions. Ejection paths are examined for the partially and totally ejected occupants.

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Based on the analysis, the magnitude of the opportunities for injury and harm reduction through safety enhancements such as air curtains and safety belts designed for rollover protection is examined.

Paper No. 07-0279-O

NHTSA Research On Improved Restraints In Rollovers

Michael Sword, *Transportation Research Center*
Lisa K. Sullivan, *National Highway Traffic Safety Administration, United States*

Abstract:
NHTSA has reinitiated a program to characterize restraint system response in rollovers. A rollover restraint tester (RRT) is utilized to produce a 180 degree roll followed by a simulated roof-to-ground impact. Recognizing the unpredictability of the real world rollover phenomenon, this test provides a repeatable and consistent dynamic for suitable lab evaluation. Similar NHTSA research during the mid-1990's demonstrated an excursion reduction of up to 75% when an inflatable belt was compared to the standard 3-point belt with a 50th percentile male. A complete detail of this work is outlined in 16th ESV Paper No. 98-S8-W-34 titled Evaluation of Restraints Effectiveness in Simulated Rollover Conditions

Technologies being considered include integrated seat systems, pyrotechnic and electric resetable pretensioners, 4-point belt systems, and inflatable belts. High speed video data is collected and analyzed to examine occupant head excursion throughout the tests and will be presented for discussion. Though repeatable, concern about the real world relevancy of the RRT dynamics have been focused toward an absence of a mechanical component for lateral motion. This component is not inbuilt to the test fixture.

The work attempts to determine if reasonably reduced excursion is possible in the simulated rollover. This research has been constrained to examining restraint systems focused to the seat. Future research to include a partial vehicle cab structure is planned to allow evaluation of devices that utilize it for a reaction surface; such as rollover airbags. Automotive suppliers are working to improve restraint systems for rollover accidents.

Restraint advancements have primarily been focused on frontal and side crash performance. It is construed that many of these advancements can also aid in reducing occupant excursion during a rollover crash. With interest in FMVSS 216 upgrades, improving restraint effectiveness in rollovers would further enhance protection for belted, non-ejected occupants in rollovers.

Paper No. 07-0308-O

Rollover Sensor Tests - Data Analysis Methodology And Neck Loading Assessment

Bridget O'Brien-Mitchell, Stephen Cassatta, Melanie Giasson, Anthony Melocchi, Robert Lange, *General Motors Corporation, United States*

Technical Session: Structural Integrity And Restraint Performance

Abstract:
Although rollover crashes represent a small fraction (approximately 3%) of all motor vehicle crashes, they account for roughly one quarter of crash fatalities to occupants of cars, light trucks, and vans (NHTSA Traffic Safety Facts, 2004). To better understand the cause of these injuries, General Motors Corporation (GM) has developed a new procedure to summarize the kinematics of the vehicle and Anthropomorphic Test Device (ATD) along with peak Injury Assessment Reference Values (IARVs) in a rollover.

For development of rollover sensor calibrations, GM has performed an extensive number of rollover tests in the laboratory to simulate the most common initiation types for rollover crashes. Instrumented Hybrid III 50th percentile ATDs were placed in the front outboard seating positions in these tests. This paper details an assessment of vehicle and ATD orientations and ATD contact locations for the subset of events during which an IARV was exceeded. An analysis methodology for the data is proposed in combination with a discussion of the physics of the events. Using this new procedure, GM was able to identify common trends of peak IARVs relative to restraint use and rollover initiation type.

IARVs were shown to be exceeded in all test types and with both belted and unbelted ATDs. Although ATD motion was unpredictable, test type did have some effect on the location of ATD contact. In addition, the location of contact of leading side ATDs was controlled more by test type than by restraint usage. IARVs were shown to be exceeded with the vehicle at a wide range of orientations. Any event during which the motion of the ATD head was arrested prior to arresting the ATD body showed the potential for exceeding a neck compression duration assessment reference value, regardless of vehicle orientation or the location of head contact.

Paper No. 07-0361-O

Results From Two Sided Quasi-Static (M216) And Repeatable Dynamic Rollover Test (JRS) Relative To FMVSS 216 Tests

Don Friedman, Carl Nash, *Center for Injury Research*
Justin Caplinger, *Xprts, LLC, United States*

Abstract:
In an attempt to find a test protocol that characterizes the rollover occupant protection capability of a passenger vehicle better than the test used in Federal Motor Vehicle Safety Standard 216, we developed equipment and protocols for a modified, quasi-static roof crush test (M216, a test conducted sequentially on both sides of the roof over the A pillars at a pitch angle of 10º and roll angles of 25° and 40° respectively) and for a repeatable, dynamic rollover test called the Jordan Rollover System (JRS).

We have conducted JRS tests on 12 production vehicles to determine roof intrusion and intrusion velocities at a number of points in the interior. These tests included complete production vehicles, body bucks at reduced weight to increase the roof strength-to-weight ratio, and pairs of identical vehicles where one has had the roof reinforced in a manner that is entirely hidden by the vehicle's sheet metal and

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upholstery. Data from the JRS tests and the M216 tests are compared with the results of FMVSS 216 tests.

Analyses of the data highlight the relative value and validity of each test methodology, its ability to predict roof performance in actual rollovers, its use in vehicle roof structure design, and its potential contribution to regulation or consumer information. Based on the roof intrusion and intrusion velocity in the vicinity of front seat occupants' heads, we propose a rollover crashworthiness rating system. While static tests measure the force and deformation of the roof on the outside, the dynamic tests measure the intrusion on the inside where it is directly related to the occupant's survival space and injury potential.

Paper No. 07-0074-O

Development Of Proposed Crash Test Procedures For Ambulance Vehicles

Nadine Levick, *Objective Safety LLC, United States*
Raphael Grzebieta, *Monash University, Australia*

Abstract:
Ambulance vehicle occupant protection, crashworthiness and safety testing lags 30 years behind general automotive safety and crashworthiness. Ambulance vehicles are a unique passenger environment with complex crashworthiness and occupant protection issues, eg. occupants in various orientations, unique human factors aspects and an array of aftermarket interior modifications. This paper proposes crash test procedures for such vehicles based on manufacturer and consumer conducted pre-modification crash tests and previous ambulance sled and full scale crash tests.

A typical ambulance vehicle from one of the largest fleets globally, was considered. Based on manufacturer specifications, crash test data for the vehicle, inspections and other published data regarding ambulance vehicle crashes, sled and crash testing - an impact testing procedure was developed by a multidisciplinary team. Assessment and development focused on vehicle crashworthiness performance and real world human factors aspects of aftermarket interior modifications.

Frontal and side impact crashworthiness testing profiles for this vehicle were determined and developed inline with parameters outlined in ASA 1754 (ambulance restraint systems standard). The testing profiles included a recumbent occupant, rear and forward facing seated occupants, 50th and 95th percentile ATDs, with side impact ATDs for rear seating positions in the side impact tests.

Ambulance vehicle safety testing and design should be driven by accepted automotive safety practice. In a setting of high crash rates, a complex occupant and emergency care environment, and the absence of prescribed dynamic crashworthiness test procedures for ambulances - the proposed test procedures in this paper provide a first approach to describe the technical development of comprehensive crash testing profiles in this setting. Such profiles for this environment will ensure that system safety can be ascertained and optimized, and support safety enhancements for ambulance vehicle development.

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Paper No. 07-0350-O

Experimental Investigation Of The Energy Absorption Capability Of Continuous Joined Crash Boxes

Lorenzo Peroni, Massimiliano Avalle, Giovanni Belingardi, *Politecnico di Torino, Italy*

Abstract:

In the design of vehicle structures for crashworthiness, there is a need for rigid subsystems that guarantee an undeformable survival cell for the passengers and deformable subsystems able to efficiently dissipate the kinetic energy. The front rail is the main deformable component dissipating energy in a frontal crash, which is the most dangerous crash situation, and for which the structural behaviour is mostly affecting.

The design of the front rail, usually consisting of a thin walled prismatic column, requires definition of the geometry, that is, of the shape and dimension of the cross section, of the thickness of the material, and of the material itself.

In this work the analysis of the effect of different cross sections of the front rail, and of the joining system is carried out. Furthermore, the collapse during crash is influenced by the loading rate since the loading speed has substantial influence on the mode of collapse and on the material behaviour. In fact, the structural materials used in this application are known to be strain-rate sensitive.

Within the work, different types of sections are compared. Different non-common continuous joining technologies are examined: three different types of adhesive an acrylic, one component epoxy and two components epoxy and laser welding. Adhesives and laser welding can be used as an alternative to the widely used spot-welding to improve the structure performance due to the continuos joint.

The effects of the loading speed are taken into account by comparing quasi-static crush tests to dynamic impact tests. Dynamic tests have been performed under a drop tower testing apparatus built within the Vercelli campus of the II Faculty of Engineering of the Politecnico di Torino.

Paper No. 07-0513-O

Accuracy Of Vehicle Frontal Stiffness Estimates For Crash Reconstruction

Hampton Clay Gabler, *Virginia Tech - Wake Forest University*

Qian Wang, *Virginia Tech, United States*

Abstract:

Research Question: Previous research has shown that NASS/CDS delta-V estimates underestimate true delta-V by 25% on average. One possible explanation for this error is inaccuracies in the stiffness values used in the delta-V reconstruction calculation. NHTSA estimates delta-V from detailed measurements of vehicle deformation using the WinSmash crash reconstruction code. The accuracy of codes, such as WinSmash, is dependent upon vehicle stiffness values computed from post-impact crush measurements in crash tests. Any error in these crush measurements will be reflected as inaccuracies in the stiffness coefficients, and ultimately as errors in WinSmash delta-V estimates. This paper investigates the accuracy of post-impact crush measurements in staged crash tests.

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Methods: The study presents the accuracy of post-crash crush measurements in NCAP tests conducted from 2000-2006 using (1) double integration of accelerometers in occupant compartment, (2) comparison of pre- and post-test vehicle length measurements, (3) frontal crush measurements using the NASS/CDS protocol, and (4) analysis of high speed video. The paper will present and compare WinSmash stiffness coefficients computed using each of these measurement techniques.

Data Sources: NHTSA Vehicle Crash Test Database, 2000-2006

Expected Results: Our hypothesis is that in rigid barrier crashes, on-board accelerometers and analysis of high-speed video are more accurate than simple manual measurements of static deformation. Our preliminary comparison of static crush using these three methods show variation as high as 10% in static crush measurements on individual crash tests.

Conclusions: Accurate stiffness measurements are the basis for NHTSA reconstruction of delta-V in real world crashes. Errors in static crush measurements will be reflected as inaccuracies in the stiffness coefficients, and ultimately as errors in WinSmash delta-V estimates.

Limitation of Study: The study is limited to frontal crash tests and to the effect on longitudinal delta-V calculation

What does this paper offer that is new in the field? Estimates of structural stiffness from late model vehicles using traditional and improved measurement technologies.

Paper No. 07-0202-O

The Mechanism Of Belt Induced Chest Deflection: Analysis And Possibilities For Reduction

Burkhard Eickhoff, Erik Forster, Harald Zellmer, *Autoliv B.V. & Co. KG, Germany*

Abstract:

A precondition for a good rating in Euro-NCAP frontal impact is a low value for chest deflection. To achieve this, detailed knowledge of the mechanism of chest deflection is needed. Consequently, the objectives of this study were a detailed analysis of the belt induced chest deflection and a finding of solutions to reduce it.

Theoretical investigations as well as simulation (software Madymo 6.1) were used to study the mechanism of chest deflection. The simulation environment represented a typical middle class vehicle. A special simulation dummy which allowed a detailed analysis of the internal and external forces acting on the thorax was used. Finally, sled tests were carried out in order to confirm the theoretical and numerical results.

For the environment investigated, the belt force turned out to be the dominant factor for chest deflection. In fact, the value for chest deflection showed a good correlation to the arithmetic mean of the shoulder

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belt force (FB3) and the force of the inner diagonal belt (FB4). While FB3 is commonly limited by a load limiter in the retractor, FB4 is strongly influenced by the forces in the lap portion of the belt. These forces are usually 1kN to 2kN larger than the level of load limitation. Preventing the belt slippage through the buckle tongue proved to substantial reduce FB4 and, thus, chest deflection in tests with EuroNCAP deceleration pulse.

A prototype of a locking tongue was developed and sled tests were carried out in different vehicle environments. It was shown that depending on belt geometry a reduction in chest deflection of 10-25% could be achieved.

Paper No. 07-0481-O

Procedure To Assess Submarining In Frontal Impact

Stéphane Couturier, Jacques Faure, *Renault SAS,*
Julien Hordonneau, *IDESTYLE, France*
Ricardo Satué, Joaquim Huguet, *Applus+ IDIADA, Spain*

Abstract:
This study addresses the submarining issue left in frontal impacts today in the passenger cars, and proposes a methodology to assess it. The first part briefly describes the submarining phenomenon that consists of a sliding of the lap belt above iliac spine due to either bad safety belt geometry or poor coupling of the occupant to the car. This mechanism results in severe abdominal injuries (mesanterin laceration, severe hemoperitoneum, perforation,…). Some recent accident data coming from LAB (Laboratoire d'Accidentologie et de Biomécanique) are also presented in order to highlight the increasing importance of this phenomenon as the compartment intrusion is reduced, the knee support area is eliminated in order to avoid other injuries and the use of the seat belt is generalized in passenger car rear seats. The second part explains the reasons why, despite of evidence review, this phenomenon is not taken into account today, neither by the regulations nor by the ratings. The HIII dummy, widely used for safety assessment, integrates a very stiff lumbar spine. This feature prevents the pelvis rotation and consequently submarining. Therefore, other widely used dummies currently available are considered in this study in order to identify a more biofidelic behavior enabling the pelvis rotation and therefore detection of submarining phenomenon. In the third part, a full procedure based on a sled test and involving these suitable dummies is proposed. Associated criteria that could be used to assess the performance of a given restraint system are also described. The procedure is applied to vehicles with or without submarining countermeasures and the results are validated using the feedback on real accident data from the LAB. The results confirm the efficiency of the countermeasures and validate the assessment procedure.

Paper No. 07-0491-O

The Benefits Of Double Pretension In Decreasing Knees & Lower Legs Injuries In Frontal Impacts

Jacques Faure, Stéphane Couturier, *RENAULT SA*
Yves Page, Maxime Labrousse, *LAB, France*

Technical Session: Structural Integrity And Restraint Performance

Abstract:
Official French accident data (provided by ONISR – Observatoire National Interministériel de la Sécurité Routière) show that 3160 car occupants have died and 18553 have been seriously injured in 2005 on French roads. It is also stressed by the LAB (Laboratoire d'Accidentologie et de biomécanique) that frontal impacts represent 45% of fatalities and 60% of serious injuries. Recent progress in passive safety, coming from both regulation enforcement and consumers ratings allowed to solve most of the fatal issues in frontal impact which are for example :

- intrusion (steering wheel, firewall, footwell,…), that is now decreased through absorbing structure designed to provide a good self-protection level
- head contact (with steering wheel…) now avoided with frontal airbags
- chest injuries, reduced with belt load limiters

The aim of the presentation is to focus on the evolution of lower legs serious injuries (knee, femur and hip) throughout the last vehicles generations, and to find out the benefits of advanced restraints systems such like double pretension.
The first part of the presentation is dedicated to an explanation of the double pretension system fitted on most of the cars in the Renault line-up. Comparative crash-tests have been performed with protocol currently existing, to show the effectiveness in term of pelvis restraint of the double pretension compared to a single one.
The second part is a review of recent real accident data provided by the LAB (Laboratory of Accidentology and Biomechanics). Lower legs injuries data have been collected on modern vehicles fitted with a double pretension and these data are compared with those of the rest of the fleet, in order to check the effectiveness of the double pretension seen in crash tests.

Paper No. 07-0168-O

Simulated Pregnant Occupant Injury Risk Calculated From NCAP Vehicle Crash Tests

Sarah Manoogian, Stefan Duma, *Virginia Tech – Wake Forest, Center for Injury Biomechanics*
David Moorcroft, *Federal Aviation Administration, Civil Aerospace Medical Institute, United States*

Abstract:
Automobile crashes are the largest single cause of death for pregnant females and the leading cause of traumatic fetal injury mortality in the United States. A previously validated MADYMO computer model of a 30-week pregnant occupant was used in this study to investigate the pregnant occupant response in a New Car Assessment Program (NCAP) frontal barrier motor vehicle crash. The effect of the restraints, all tests had a 3 point seatbelt and an airbag, and the vehicle performance in the crash are incorporated by applying the measured pelvic acceleration in the front seat passenger to the pregnant occupant model. Included in the study are nine vehicle models that represent the compact, medium, and sport utility vehicle classes during the years 1996 to 2006 for a total of 26 NCAP tests with corresponding simulations. Uterine strain from the computational model, a good predictive measure of the risk of fetal injury due to placental abruption, indicates the average risk of adverse fetal outcome associated with these NCAP tests is 85.3 ± 13.4 % with a minimum risk of 55.4% and a maximum risk of 100.0%. NCAP

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star rating correlates with the risk of adverse fetal outcome (p=0.001); 3 stars has an average risk of 98.5 ± 2.7 % (n=3), 4 stars has an average risk of 89.1 ± 11.0 % (n=14), and 5 stars has an average risk of 74.9 ± 12.5 % (n=9). However, even the best NCAP rating, 5 stars, is still indicative of a high risk of fetal injury. This high risk is consistent with published pregnant occupant case studies that have an equivalent change in velocity of approximately 35 mph. Although this study is limited to computational modeling, it suggests more research in protecting the pregnant occupant is needed.

Paper No. 07-0224-O

Effectiveness Of Seat Belt For Rear Seat Occupants In Frontal Crashes

Koji Mizuno, Nagoya University
Takahiro Ikari, Kenich Tomita, *National Agency for Automobile Safety and Victim's Aid*
Yasuhiro Matsui, *National Traffic Safety and Enviromental Laboratory, Japan*

Abstract:
In Japan, there are campaigns by several organizations to wear a seat belt in rear seat occupants. To see the effectiveness of seatbelt for the rear seat occupant injury risks, full-frontal crash tests were carried out by the National Agency for Automotive Safety & Victims' Aid. In this paper, injury risks of occupants in the rear seat with and without seat belt were examined using the NASVA test data. The AF05 and Hybrid III three-year-old were positioned in the rear seat. First test was with seat belt wearing and second test was without seat belt. For belted AF05 and Hybrid III 3YO, there were no head contacts with car interior. However, the chest deflection of AF05 was large, which was likely to lead rib fractures.
For the unbelted test, the AF05 rear seat impacted its knee against front seat back and its head against the head of the driver dummy. Injury risks to the head and the femur was extremely high for the AF05. As the seat back was impacted by AF05 in the rear seat, the chest acceleration of the driver dummy in the rear seat became high. The unbelted Hybrid III 3YO flied in the compartment and dropped on the instrument panel. Although measured injury criteria were small, the Hybrid III 3YO made contact with several locations and injury risks could be high depending on the contact locations.
The trend of acceleration in the passenger compartment was also examined using JNCAP data. As the compartment strength has become high, the acceleration is becoming high, especially for small cars. Therefore, the crash tests demonstrated the effectiveness of wearing seat belt for rear seat occupants. However, there will be some points to be improved for restraint system in the rear seat such as reducing chest deflection because the compartment acceleration is becoming high for the current cars.

Paper No. 07-0388-O

Intelligent Seatbelt Reminders: Do They Change Driver Seat Belt Use In Europe

Anders Kullgren, Maria Krafft, *Folksam Research, Karolinska Institutet*
Anders Lie, *SRA, Karolinska Institutet*
Claes Tingvall, *SRA, Monash University, Sweden*

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Abstract:
The objective was to study if there were differences in driver's seat belt wearing rates between cars with and without Seat Belt Reminders (SBRs), and if there were differences in wearing rates between some different European countries indicating that the potential in saving lives could vary between the counties.

The influence on seat belt wearing rates of SBRs fulfilling the EuroNCAP specification was studied in seven EU countries; Belgium, Denmark, France, Germany, Italy, Spain and Sweden. The same observer performed all observations and he noted if the seat belt was used and the car model observed. In total 11160 cars were observed. The measurements were only made in cities and did only concern driver SBR.

For all observations the total seat belt wearing rate was 97.5% in cars with SBR, while it was 85.8% in cars without. The highest wearing rate in cars with SBRs was found in Paris, 99.8%, and the lowest in Brussels, 92.6%. In Sweden approximately 75 lives could be saved every year if all cars were fitted with SBRs. In the EU the corresponding number is 7000 lives.

It was concluded that SBRs have a dramatic impact on the number of fatally and seriously injured car occupants. An average seat belt wearing rate of 97.5% was observed in cars fitted with SBR. In the EU approximately 7000 lives per year could be saved if all cars were fitted with SBRs. Therefore actions aimed at increasing the fitment rates of SBRs are desirable.

Previously it has been estimated that SBRs are one of the most cost effective measures to save lives. The results in this study support the estimation. The influence of SBRs on seat belt wearing rates in several countries has not been shown earlier.

Paper No. 07-0349-O

Evaluation Of Advanced Airbag Field Performance Using Event Data Recorders

Hampton Gabler, *Virginia Tech*
John Hinch, *National Highway Traffic Safety Administration, United States*

Abstract:
Research Question: How are advanced occupant restraint systems, designed to advanced air bag criteria specified in the US FMVSS-208, performing in the field?

Methods: Analysis of Event Data Recorder data downloaded as part of National Automotive Sampling System (NASS)/Crashworthiness Data System (CDS) crash investigation. Although advanced restraint systems have been extensively tested in the laboratory, we are only beginning to understand the performance of these systems in the field. Because Event Data Recorders record many of the inputs to the advanced airbag control module, these devices can provide unique insights into the performance of airbags in the field.

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Data Sources: NASS/CDS 2001-2005 with associated EDR data contained in the Virginia Tech EDR database.

Expected Results: For vehicles with EDRs and manufactured in compliance with the current US FMVSS 208 standards, the paper will present the frequency and nature of how airbag deployment (number of stages and trigger time) varies with belt status, how airbag deployment varies with crash severity, late deployments, and the frequency and nature of frontal crashes in which the airbag did not deploy.

Conclusions: Event Data Recorders can identify features of airbag deployment algorithms which may not be apparent from crash testing. Methodical examination of EDR records can identify deployment patterns of multi-stage inflator systems, those types of collisions likely to result in late deployments, and the characteristics of crashes which result in no-fire decisions.

Limitation of Study: The Virginia Tech EDR database is composed primarily of EDR downloads from General Motors Vehicles.

What does this paper offer that is new in the field? This is the first paper of its kind to analyze the field performance of advanced restraint systems using Event Data Recorders.

Paper No. 07-0265-O

The Application Of CAE In The Development Of Airbag Restraint System Performance For A Certain Vehicle

Jang-Mook Lim, Hyung-Wook Park, Seok-Ho Hong, Ju-Yup Lee, Kwan-Hum Park, Kim Bum-Jin, *Hyundai Motor Company, Republic of Korea*

Abstract:

If vehicle manufacturers have an airbag sensing algorithm, they could use this algorithm to find optimal airbag sensor locations for the better airbag sensing performance, to get an optimal firing logic for their certain vehicle, and to get the overall good performance by considering both the vehicle structure and the airbag sensing algorithm. One study in this paper shows how to find the optimal locations of front impact sensors (FIS) using in-house airbag sensing algorithm, crash test data and CAE simulation models. For this purpose, three steps are fulfilled as follows. In the first step, the acceleration sensor signals of the crash tests are collected at several positions of the vehicle. In the second step, the full car crash simulations are made and correlated to the crash test data. Using these well defined crash vehicle models and crash test data, the acceleration signals of the FIS candidate locations, such as radiator, front side members, and bumper back beam, are obtained. In the final step, using these acceleration signals and airbag algorithm, the airbag sensing performance are evaluated, and the final candidate positions are selected. The robust FIS positions are selected effectively for various crash conditions and velocities via this approach.

The other study shows how to determine an airbag deployment logic using CAE. From simulation models which have several crash speeds, several crash modes, and several restraint conditions, the airbag deployment logic can be determined to minimize the occupant injury level.

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In addition, the roles and limitations of CAE simulations are demonstrated in the airbag algorithm calibration process and the airbag restraint system development.

Paper No. 07-0309-O

Application Of Numerical Methods To The Simulation Of The Earliest Stages Of The Airbag Deployment

Daniel Muñoz, Julia Carlón, Alberto Negro, Alberto Mansilla, Roberto Martín
Fundación CIDAUT, Spain

Abstract:
The application of numerical techniques to the study of the phenomena that occur during the first milliseconds after the activation of the airbag has remained up to recently out of reach, due to the high complexity of the problem. On the one hand, the highly dynamic evolution of the gas produced by the inflator invalidates the hypothesis of uniform pressure within the volume. On the other hand, the simulation of the airbag opening involves problems such as the creation of extremely complex meshes representing the folded bag inside its housing, characterization of the behaviour of strain rate dependent materials, breaking of tear seams, etc.
During the last years several simulation packages have introduced modules to reproduce the gas flow inside the airbag, but the experimental methods used most commonly to validate simulations involving airbags are not able to deal with the high speed and lack of accessibility that characterize this stage of the airbag deployment.
The objective of the presented works is the determination of the capability of these simulation tools to be used in the design of parts attending to the loads produced during the opening of the airbag. This will help us not only to improve the development and integration of components, but, in later steps, to provide airbag models able to be applied with guarantees in the simulation of OOP.
In order to do this, a combined methodology using simulation and instrumentation has been defined, based on the definition of numerical models using the FEM software Pam-Crash and its module for simulation of fluids based on the algorithm FPM. These models have been validated with experimental tests specifically designed for this task. This paper intends to introduce the particularities of this stage of the airbag deployment and shows some of the results of the mentioned works.

Paper No. 07-0073-O

Injury Optimization of the Frontal Crash Supplemental Restraint System (SRS) Deployment Matrix

Ryan Miller, Brian Allen, *Honda R&D Americas Inc., United States*

Abstract:
Injury Optimization of the Frontal Crash Supplemental Restraint System (SRS) Deployment Matrix
With the introduction of the FMVSS 208 upgrade for U.S. frontal crash safety, many new requirements were added for frontal crash safety. In order to meet these new requirements, manufacturers had to develop new methodology for sensing, controlling, and deploying airbags. The standard achievment method is to use dual stage airbags with two firing thresholds.

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The objective of this research was to improve three key areas of the standard method:

1) Prevent risk of inadvertent high output deployment for small occupants.
2) Improve occupant injury by achieving the ideal deployment mode
3) Reduce the complexity of the system to increase robustness.

In order to achieve these goals, it was proposed that a single ideal deployment mode could be developed by performing a parametric study where TTF and the delay timing between firing the first and second stage were varied independently for the driver and passenger ATDs. This was done for AM50% and AF5% ATDs in a front 40km/h unbelted test mode. Once the 'ideal' TTF/delay was determined, the test speed was increased to 48km/h and 56km/h respectively for both belted and unbelted occupants.
The research showed that for the driver, an early TTF (10-15ms) with a 20-30ms delay provided the best combination of restraint for both the AM50% and the AF5% ATD. This also allowed for good injury results in the AF5% low risk deployment mode.
For the passenger, an early TTF (10-15ms), with a longer delay (130ms) showed the best combination of injury results. This allowed for successful OOP deployments as well as good frontal crash results. It was also discovered during this research that there are some key interior lay out items that must be maintained in order to use this type of deployment strategy.

Paper No. 07-0234-O

The Crash Problem For Advanced Restraints

Ana Maria Eigen, Sarah L. Bentil, David Smith, *National Highway Traffic Safety Administration, United States*

Abstract:
In response to evolving sensor and occupant retention technologies, NHTSA will soon begin cooperative research to develop test procedures for advanced occupant restraints. These restraints will be real-time adaptive to a variety of crash severities and occupants. They will address such problems as improving belt effectiveness in front-front crashes to higher than the current level of 50% and to make them better suited for rollover and offset crashes. The research will address: identification of potential improvements in current restraints, identification of minimum performance and objective testing, as well as performance metrics, and calculation of benefits inherent in such improvements. This work necessarily involves the identification of a target crash population, estimations of the effectiveness of advanced restraints from test and evaluation, and benefits calculation based upon the target population and the effectiveness estimates. This paper is an initial analysis of the advanced restraints target population for advanced restraints.

NASS CDS was chosen for the initial work owing to its complete crash, vehicle, occupant, and injury reporting. In addition, in order to maintain a focus on recent vehicle designs and performance, the most recent eight years of data will be used for an occupant population that contains only belted drivers and passengers. By analyzing this population we focus our attention on the current performance of restraints.

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The MAIS 2+, 3+ and fatal, restrained, occupants will be quantified. Disaggregations of primary direction of force, impact area, and injury types, among others, will be computed across all crash types in order to develop an understanding of the requirements for advanced restraint prototype designs and the later computation of benefits.

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Oral Presentations | Tuesday, June 19, 2007 | 8:30a.m.-1:00p.m.

Chairperson: Bernie Frost, UK | Track B | Amphitheatre Pasteur
Co-Chairperson: Claudio Lomonaco, Italy

Paper No. 07-0318-O
A Review Of The European 40% Offset Frontal Impact Test Configuration
Richard Cuerden, Mervyn Edwards, Rebecca Cookson, Phillip Massie, *TRL Limited, United Kingdom*

Abstract:
Frontal impacts are the most frequent crash type and account for the majority of Killed and Seriously Injured (KSI) car occupant casualties in Europe. This study reviews the performance of modern cars (registered in 1996 or later) in frontal impacts, which are most associated with KSI casualties. Comparison is made with the 40% offset legislative (UNECE R94) and consumer (EuroNCAP) tests. The aim of the study is to evaluate how well the 40% offset configuration and the associated vehicle loading and intrusion factors represents the real life injury experience sustained in frontal impacts.
Co-operative Crash Injury Study (CCIS) data collected from June 1998 has been used. There were 806 KSI seat belted casualties who experienced frontal impacts and were occupants of cars registered in 1996 or later. The majority of these victims were drivers. The study then analyses 435 drivers who had impacts that involved direct contact to the front right corner of the car. The nature of the vehicle loading in terms of structural features is considered and compared with the injury outcome and the associated mechanisms.
Car to car impacts are the most common, although larger goods and passenger vehicles are prominent among crash partners in fatal crashes. About 80% of the fatalities are encompassed by the EuroNCAP frontal test speed rising to 95% of the seriously injured survivors.
More than half of the KSI car occupants sustain their injuries in impacts with more than 40% overlap and a significant proportion of these crashes involve direct loading to both longitudinals. Thoracic injuries caused by seat belt loading and lower extremity injuries caused by facia and footwell contact are the main body regions injured. Approximately 80% of the MAIS=2 and 50% of the MAIS 3+ injury is sustained by survivors with little or no intrusion to the compartment (<10cm).

Paper No. 07-0423-O
Review Of Side KNCAP On The Vehicle Structures And Occupant Protections
Younghan Youn, *Korea University of Technology and Education*
Gyu-hyun Kim, *Korea Traffic Safety Authorization*
Sang-do Kim, Won-man Chung, *Ministry of Construction and Transportation, Republic of Korea*

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Abstract:
The Ministry of Construction and Transportation of Korea (MOCT) has been conducted the side impact crash tests for the new passenger vehicles as a Korean New Car Assessments Programs (KNCAP) and provided crashworthiness and safty information to the public since 2003. Nine compact passenger cars, four medium passenger cars and three SUVs and two Van type vehicles were evaluated according to the Korean side impact test protocols. Based on the test results, the most dominant factor for good star rating is the rib deflections of EuroSID I. The next main factors are abdominal forces and pubic symphysis forces. Since KNCAP side impact program has been introduced, year after year, the newer vehicles gained the better grades. The least influencing factors were viscous criteria and head injury criteria. Especially, all SUVs and Vans with R-point over 700 mm get five stars with the perfect 4 points on HICs. The main purpose of this study is to evaluate the trends of strength of vehicle structure changes, interior package design parameters, protection zone of side impact airbag or type of airbags to add an additional counter measures of side impact performances, such as a pole type impact test.

Paper No. 07-0453-O

The Effect Of Impact Environment On Occupant Risk And The Belted/Unbelted Dilemma

Guy Nusholtz, Murthy Kowsika, Jianqing Xue, Guglielmo Rabbiolo, Laura Di Domenico, Yibing Shi, Famili Fariba, Lynn Byers, *DaimlerChrysler Corporation, United States*

Abstract:
A data-based model, previously developed, is used to estimate the influence of parameters that control intrusion on the overall fleet wide fatality risk in frontal impact vehicle crashes. Data on accident statistics and accident velocity distribution are obtained from FARS, NASS and State databases. The vehicle impact response characteristics that are required to run the model is derived from vehicle to vehicle crashes, NASS CDS and GES as well as NCAP test data. Due to lack of sufficient data on intrusion resistance in the accident databases, the vehicle intrusion ranking determined from IIHS ODB tests is used. The parameters included in the investigation are “intrusion” and vehicle “stiffness”, for both belted and unbelted conditions. Simulations are performed to study the effects of limiting intrusion by stiffening the front structure on the overall occupant risk. The inferences obtained from the model are compared with the fatality risk assessed from accident data for different classes of intrusion resistant vehicles. Results indicate that the optimal vehicle stiffness to minimize occupant risk for belted and unbelted conditions is different. Limiting the vehicle’s intrusion by stiffening may reduce the occupant risk at the high impact velocities; however, it is counter-productive at low impact velocities and, may have no value overall in the current fleet for the current accident velocity distribution. Statistical analysis of the fatality risk for different classes of intrusion resistant vehicles has not shown any significant changes in fatality risk. Similar inferences are also obtained when the study is extended to include EuroNCAP test data.

Paper No. 07-0219-O

Research Into New Side Impact Test Based On Accidents In Europe And Japan

Taisuke Fujiwara, Hiroyuki Murayama, *Toyota Motor Corporation, Japan*

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Abstract:
The current test procedures provided by the side impact regulations and ratings in Europe and Japan are to strike non-crabbed MDB to a stationary test vehicle. However, in real world accidents, majority of struck vehicles are not stationary but moving at the impact time. Consequently, it is necessary to consider velocity of struck vehicles as well as one of striking vehicles.
Thereupon, the car to car side impact tests were conducted under the conditions that struck vehicles were both stationary and moving to investigate the differences. As a result, as reported before, the maximum cabin intrusion was larger and the most sever when a struck vehicle was stationary, but it has become clear that the different deformation modes occurred in each condition and lead different structural modifications to improve occupant safety. In addition, according to the accident data of Europe and Japan analyzed at the same time, the number of the accidents which happened while struck vehicles were moving is high in both regions. Therefore, it becomes clear that considering the velocity of both striking vehicles and struck vehicles is necessary. Based on these results, a new procedure of the side impact test has been developed. The procedure simulates accidents happened in real world using AE-MDB which has the same front end strength as striking vehicles' in both Europe and Japan, and the AE-MDB trolley moves with crabbed angle. The procedure enables us to adjust severity of test conditions by changing the weight and velocity of the AE- MDB trolley in accordance with the states of accidents happened in real world. It is absolutely essential to simulate real world accidents like this to advance appropriate countermeasures against the side impact.

Paper No. 07-0058-O

A Study Of US Crash Statistics From Automated Crash Notification Data

Mukul Verma, Robert Lange, Daniel McGarry, *General Motors, United States*

Abstract:
Knowledge of parameters defining automobile crashes is of great significance in developing priorities and countermeasures for reducing the associated societal harm. Historically, motor vehicle safety researchers examined selected vehicles involved in crashes, measured residual deformation patterns, applied conventional modeling techniques and known algorithms and calculated various collision parameters such as dissipated kinetic energy, post-collision vehicle motion and change in velocity, etc. Such post-crash reconstructions are known to be limited in terms both of the amount of information that can be generated as well as the precision of the results.

This paper analyzes data available as part of telematics-based automatic collision notification in vehicles equipped with OnStar. Such data from vehicle sensors is intended to enhance the effectiveness of emergency services in providing timely and appropriate care to the vehicle occupants involved in serious crashes. For the present study, any information that uniquely identifies customers was removed and only vehicle-based parameters were studied. This data was utilized to calculate the parameters indicative of crash severity for all frontal crashes exceeding certain thresholds in vehicles with this system. The distribution of velocity change during the crash was obtained for a large number of cases and is presented here. In addition, the data transmitted following collision also enabled the estimation of the time

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period during over the velocity changes occur, thereby enabling a better estimation of crash severity than possible from conventional methods. Since injury parameters measured in tests are related to the crash severity as defined by mechanical 'power', the availability of the information regarding the time period for maximum velocity changes greatly enhances the value of crash data in determining potential solutions for improving traffic safety.

Paper No. 07-0225-O

Near-Side Occupants In Low Delta-V Side -Impact Crashes: Analysis Of Injury And Vehicle Damage Patterns

Mark Scarboro, Rodney Rudd, *National Highway Traffic Safety Administration*
Mark Sochor, *University of Michigan, United States*

Abstract:
Near-side occupants in side-impact crashes often sustain severe injuries resulting in significant economic burden. Continual advancements in safety technology, including reinforced door structures, torso and head curtain air bags, compatibility improvements and other advancements, attempt to provide increased protection to occupants in these side-impact crashes. Despite these advancements, serious injuries continue to occur at delta-Vs below current side-impact crash test requirements. In this paper, detailed analysis of field crash data will show which factors have the most influence on occupant outcome in these side-impact crashes.

Nearly 200 side-impact crashes from the CIREN, NASS, and SCI databases were selected based on crash criteria including a delta-V below 42 km/h and a PDOF between 30 to 100 degrees or 260 to 330 degrees. Cases were also restricted to those in which the front-row near-side occupant sustained an AIS 3+ injury to the head, torso, abdomen or pelvis. Analyzing anatomical injury in conjunction with the vehicle damage patterns allows for the development of injury causation scenarios, which can speak directly to the interaction of the occupant and the components of the vehicle during the crash. The findings will identify trends and potential areas of improvement for future side-impact testing and design.

Outline: This paper will review nearly 200 near-side occupants in side-impact crashes from CIREN, NASS and SCI. These cases all result in AIS 3+ injury, and have Winsmash-calculated Vs less than 42 km/h. Injury patterns, crash dynamics and occupant kinematics will be reviewed to determine loading conditions on the case occupant. Detailed injury causation scenarios will be developed for each case occupant sustaining thoracic, pelvic or abdominal (liver or spleen) AIS 3+ injury. An analysis of crash, vehicle, restraint and occupant factors will be presented.

General Thrust/Point of Presentation: Identify possible trends or areas of interest related to near-side occupants sustaining serious injury in side-impact crashes.

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Detail of Audience: General audience of ESV Conference includes vehicle safety researchers from around the world representing government agencies, academia, vehicle manufacturers, suppliers, and safety advocates.

Paper No. 07-0213-O

Side Air Bag Out-Of-Position Testing Of Recent Model Year Vehicles

Allison E. Louden, *National Highway Traffic Safety Administration, United States*

Abstract:

Side air bags (SABs) are becoming more of a standard feature in the emerging vehicle fleet. These systems appear to offer superior protection in side crashes. Vehicle manufacturers are increasingly adding larger curtains that cover the entire window and two or three rows of seating. Currently, there is not any FMVSS performance requirements related to the out-of-position (OOP) performance of side air bags. Therefore, the National Highway Traffic Safety Administration (NHTSA) conducts research tests to monitor this performance, including for the rear seat positions.

The NHTSA has been monitoring this performance in vehicles over the last several years (MY 2000 – MY2005), guided by the Technical Working Group (TWG) Procedures. This study uses the Hybrid III 3-year-old, 6-year-old and SID-IIs dummies in different OOP test modes for all rows of the vehicle. The TWG document is a voluntary procedure that addresses a number of OOP testing procedures with the main focus on thoracic airbags, primarily in the front seats. The dummy responses from tests of side air curtains were all below the injury assessment reference values (IARVs). The dummy responses from tests of door and seat-mounted side air bags were also generally below the IARVs, but some OOP positions in some vehicles did result in responses that were elevated or exceeded the IARVs.

As more vehicles add side air bags, the NHTSA would like to monitor how the air bags are affecting the OOP occupants in all seating positions. This air bag monitoring research is planned to continue as the new rule is issued and is phased in. Currently the NHTSA relies on the manufacturers to provide voluntary feedback on whether they have passed the TWG procedures. NCAP and Research are currently monitoring the vehicle fleet, especially new or newly redesigned models.

Paper No. 07-0173-O

Investigation Into A Restraint System Device Addressing Different Occupant Seating Positions And Real World Accident Scenarios

Jörg Hoffmann, *Toyoda Gosei Europe NV, Germany*
Masaya Sakamoto, Kazuaki Bito, *Toyoda Gosei Ltd., Japan*

Abstract:

The development of occupant restraint systems continues to evolve as a new regulations and consumer demand. This drives to more complex solutions. Traditional seat belt and airbag designs are giving way to

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more intelligent systems that respond to crash and occupant conditions. In regulated vehicle compliance safety tests, restraint performance is usually judged against injury criteria that differ with respect to occupant size. From NASS/CDS accident data investigation it can be observed that the vehicle occupants on passenger side seat more often from neutral to most rear seat position. This paper will discuss an approach of a multi surface passenger airbag devised to enhance the protection of passenger occupants under different frontal collision scenarios in a range of varying occupant seating positions and occupant sizes. A design of experiments was carried out that adjusted parameters of the restraint system including seat belt load limits, inflator outputs and various airbag shapes. This paper documents a new approach to a restraint system component as it looks behind specific test requirements to real world accident scenario comparison.

Paper No. 07-0274-O

A Study On Invisible Knee Airbag Cushion Shape Design Using DOE Method

Soongu Hong, Hunhee Jeong, Byungryong Cho, Ikwhan Kim, *Hyundai MOBIS Research Center, Republic of Korea*

Abstract:

Recently, the OEM has become more interested in knee injury, particularly in the applications and developments of knee airbag module in a vehicle to achieve a good rating during EuroNCAP and IIHS test. Also, EuroNCAP and IIHS press OEM to equip knee airbag for occupant safety improvement and give some benefit regarding knee airbag equipped vehicles at barrier test.

Therefore, the invisible knee airbag module has been independently developed through design, simulation, static deployment test and knee impact test. But it was very difficult to position the knee cushion in case of short space between IP lower panel and knee surface. To overcome this problem, DOE (Design Of Experimental) method has been applied on knee airbag cushion shape and folding methodology using the blow test. And the verification test results are presented. Also, some design considerations for invisible knee airbag cushion shape and folding methodology are discussed in this paper.

Paper No. 07-0046-O

Status Of NHTSA's Hydrogen And Fuel Cell Vehicle Safety Research Program

Barbara Hennessey, Nha Nguyen, *National Highway Traffic Safety Administration, United States*

Abstract:

In 2006 the National Highway Traffic Safety Administration (NHTSA) initiated a research program focused on providing critical safety information on hydrogen-powered fuel cell and internal combustion engine (ICE) vehicles. Safety information is vital to support the launch of the FreedomCAR and Hydrogen Fuel Initiative, a cooperative automotive research partnership between the U.S. Department of Energy, the U.S. Council for Automotive Research (USCAR), and fuel suppliers. This program was initiated as part of the President's goal to reduce U.S. dependence on foreign oil, improve vehicle efficiency, reduce vehicle

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emissions, and make fuel cell vehicles a practical and cost-effective choice for large numbers of Americans by 2020.
NHTSA's safety initiative complements these efforts by conducting risk assessment studies of hydrogen fueled vehicles, based on test and evaluation procedures for safety assessment using suitable performance criteria.

The risk assessment studies identify potential failures and their consequences that could indicate unsafe conditions. Also presented is test and evaluation research that is centered on burn, burst, pressure cycling, and drop testing of representative hydrogen fuel components and systems. Additionally, the development and evaluation of an electrical isolation test procedure is presented and discussed. Finally, a comparative assessment of international fuel system integrity performance requirements is presented.

Paper No. 07-0384-O

Chest And Abdominal Injuries To Occupants In Far Side Crashes

Brian Fildes, *Monash University, Australia*
Hampton Gabler, *Virginia Tech*
Kennerly H. Digges, *George Washington University*
Michael Fitzharris, *Monash University Accident Research Centre*
Stu Smith, *GM Holden Innoveation, United States*

Abstract:
Research Question: The patterns, mechanisms and relationships of chest and abdominal injury in far side crashes were examined to highlight occupant protection solutions.
Method: An analysis was undertaken of occupant injuries in far side crashes using in-depth data. The analysis examined body region injury patterns to far side occupants by severity of the injury, looked in detail at chest injury mechanisms and internal injuries (kidney, spleen, liver, and heart), and finally studied the associations between these injuries, crash severity and injury and severity risk.
Data Source: The analysis used two in-depth databases: NASS/CDS in-depth data from the USA for the years 1995 to 2004 (n=4570 unweighted, 2,386,633 weighted far side crashes) as well as Monash In-Depth Sample (MIDS) data 1989 to 2004 (n=107 unweighted, 5,894 weighted far side crashes).
Results: While head injuries predominated in these crashes, chest and abdominal injuries were the second-most frequent source of injury in both USA and Australian far side crashes, accounting for around 23% of Harm. Injuries predominantly involved rib fracture and hemothorax from chest loading as well as disruption of the kidney, liver and spleen. Heart injuries mainly involved aorta disruption. Mechanisms of injury involved contact with the seat belt and buckle, the adjacent seat and seat back and the adjacent side interior of the vehicle. Risk and severity of injury were associated with type and severity of the crash and occupant demographics.
Discussion and Conclusion: The results of this analysis highlight priorities for protecting occupants involved in far side crashes. As promising mechanisms for securing occupants in far side crashes involve restraining the chest within the seat, it is important to know what to load and the effects of this on

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vulnerable chest regions. To date, little research is underway to address this trauma and answers are desperately required by auto manufacturers in their quest to improve vehicle crashworthiness.
Limitations: The study is limited by the quality and quantity of existing in-depth data available and by the general lack of knowledge of far side injury in real world crashes.
New Offerings: This paper is the first to conduct an analysis of chest and abdominal injuries, their mechanisms and risk factors to the level of detail it contains.

Paper No. 07-0097-O

Injury Outcomes In Side Impacts Involving Modern Passenger Cars

Ruth Welsh, Andrew Morris, *Vehicle Safety Research Centre*
Ahamedali Hassan, *Birmingham Automotive Safety Centre, United Kingdom*

Abstract:
This study examines some characteristics of side impact crashes involving modern passenger cars. The overall objective was to examine whether the nature of real-world accidents in which serious injury occurs differs from regulatory crash-test conditions.
The UK National Accident Database (STATS 19) and UK In-depth Accident Database (CCIS) were analysed to determine crash characteristics and injury outcomes in side impacts.
UK national accident data (comprising approximately 300,000 road crash records per year) shows that clear improvements in injury outcomes in side impacts have been observed when a sample of 'older' vehicle designs are compared to 'newer' vehicle designs.
In-depth accident data (including analysis of data from approximately 500 struck-side impact crashes) was then analysed to understand the nature and circumstances of crashes in which injury occurred. Analysis of the characteristics of such crashes which resulted in serious injury suggests that the conditions in terms of collision speed and height of impact (on the struck vehicle) do not usually match those of the UNECE R95 test specification.
In terms of AIS2+ injury outcomes in modern vehicles, head (28% of AIS2+ injuries to front seat occupants) and chest injuries (22%) still predominate although injuries to the abdomen (10%), upper extremity (14%) and lower extremity (including pelvis 19%) are also observed. When only AIS4+ injuries are considered, head (36%), chest (41.3%) and abdomen injuries (30.5%) comprise the overwhelming majority of injuries. The type of injury (in terms of anatomical location) was then considered together with injury contact source.
In conclusion, rates of serious injury outcome are highest in non-oblique impact modes, in accordance with the current regulatory test. The in-depth data indicate that serious injury occurs at speeds exceeding those in the current regulatory test and that a sizable proportion of bullet vehicle engage at a height above that used for the MDB in the regulatory test. Modifications to the current regulatory test procedure should be considered in order to ensure that regulation is more representative of the real world accident situation.

Paper No. 07-0310-O

Development And Evaluation Of The Side Impact Test Procedure Proposed By IHRA

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Ton Versmissen, Margriet van Schijndel, *TNO Science and Industry, The Netherlands*
Tobias Langner, *Bundesanstalt für Straßenwesen, Germany*
Mervyn Edwards, *Transport Research Laboratory, United Kingdom*

Abstract:
In Europe, the order of 10,000 car occupants die in side impact crashes annually. At the 2005 ESV conference, the International Harmonisation of Research Activities (IHRA) side impact working group proposed a 4 part draft test procedure, to form the basis of harmonisation of regulation world-wide and to help advances in car occupant protection. This paper presents the work performed by a European Commission 6th framework project, called APROSYS, on further development and evaluation of the proposed procedure from a European perspective.

The 4 parts of the proposed procedure are:

- A mobile deformable barrier test
- An oblique pole side impact test
- Interior headform tests
- Side out-of-position tests

Full scale test and modelling work to develop further the Advanced European Mobile Deformable Barrier (AE-MDB) is described, resulting in a recommendation to revise the barrier face to include a bumper beam element. Tests were also done to compare the performance of the WorldSID 50th and 5th percentile dummies and the ES-2.

An evaluation of oblique and perpendicular pole tests was made from tests and numerical simulations using ES-2 and WorldSID 50th percentile dummies. It was concluded that an oblique pole test is feasible but that a perpendicular test would be preferable for Europe.

The interior headform test protocol was evaluated to assess its repeatability and reproducibility and to solve other issues such as the head impact angle and limitation zones. Recommendations for updates to the test protocol are made.

Side out-of-position (OOP) tests applicable for the European situation were performed, which included additional tests with Child Restraint Systems (CRS) because their use in Europe is mandatory. It was concluded that the proposed IHRA OOP tests do cover the worst case situations, but the current test protocol is not ready for regulatory use.

Paper No. 07-0245-O

Enhancement Of Side Impact Protection Using An Improved Test Procedure

Marie-Laure Roussarie, Richard Zeitouni, Céline Adalian, *PSA Peugeot Citroën, France*

Abstract:

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Several groups of research have been charged to enhance the current European regulatory side impact test procedure (ECE95). The Aprosys project, funded through the 6th Framework Programme of the European Commission, proposed in 2006 a new test procedure called AEMDB (Advanced European Mobile Deformable Barrier) with:
- an updated barrier face representative of the current European fleet, including SUV,
- an increase in the mass of the trolley,
- a shift in the impact point,
- the addition of a rear occupant dummy.

Questions were raised, and not yet answered, on the added value of this new test procedure with respect to the current one, pointing out the actual influence of the AEMDB face. The purpose of our study is to highlight and quantify the extra-severity brought by AEMDB and its consequences on occupant protection and car design in side impact.

This research presents comparative study of ECE95 and AEMDB procedure thanks to full scale crash tests, component tests but also virtual testing made on several vehicles of different size (small and large family vehicles, executive cars, MPV).
The outcome shows a 30% extra-severity for AEMDB with respect to ECE95 on dummy readings and car deformation. This is not only due to the increase in the trolley weight, but also because of the improvement in the barrier face (geometry and stiffness). It also highlights that vehicle design will be impacted if AEMDB is chosen for regulation, on restraint systems (rear airbag, belt pretension, better design front airbag…) as well as on structural dimensioning.
This new procedure is representative of the last generation of European cars (its severity is clearly ranked between a test against an SUV and a passenger car). Its application on regulation and/or consumer tests will improve the protection in side impact of occupants on the roads.

Paper No. 07-0059-O

Investigation For New Side Impact Test Procedure In Japan: Effect Of Various Moving Deformable Barriers And Dummies On Injury Criteria In Side Impact Test

Hideki Yonezawa, Naruyuki Hosokawa, Yasuhiro Matsui, Shunsuke Takagi, *National Traffic Safety and Environment Laboratory*
Hidenobu Kubota, *Ministry of Land, Infrastructure and Transport*
Koji Mizuno, *Nagoya University, Japan*

Abstract:
The current barrier face employed in the ECE-R95 side impact test procedure referred to in the European regulation and Japanese regulation was developed based on the front characteristics of production cars in the 1970s. On the other hand, the stiffness of front characteristics and mass of recent vehicles have increased drastically compared to the 1960s, because subsequent countermeasures for full-rigid barrier front impact test, off-set front impact test and compatibility had to be incorporated into more recent vehicle design. Thus, the International Harmonization Research Activities Side Impact Working Group (IHRA-SIWG) has focused on a new barrier face such as the Advanced European Moving Deformable Barrier

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(AE-MDB), which reflects more recent vehicle characteristics. Additionally, the side impact test procedure employs the ES-2 dummy which represents a 50th percentile male in order to obtain the injury criteria for a person in the driver's seat. Therefore, the purpose of the present study is to investigate the effect of AE-MDB on the injury criteria and the difference between male and female dummies. In the present study, the ECE-R95 MDB or AE-MDB was impacted onto the side of a normal passenger car according to the test procedure. The ES-2 dummy or SID-IIs dummy representing a small female was set on the front passenger seat. Furthermore, the AE-MDB was impacted onto the side of a normal passenger car, where the impact point was 250 mm to the rear of the impact point determined by the test procedure. The results indicated that injury criteria from AE-MDB impact tests were higher than those from ECE-R95 MDB impact tests. The measured injury criteria revealed a difference between the ES-2 dummy and the SID-IIs dummy tests. Additionally, the present paper indicated the influence of the car-side impact position on the dummy injury criteria.
The present paper also describes the results of the pole side impact test against the normal passenger car used in the above test series according to the impact condition proposed by the FMVSS 214 draft.

Paper No. 07-0255-O

Assessment Of Occupant Protection Systems In Vehicle-To-Pole Lateral Impact Using ES-2 And WorldSID

Thomas Belcher, Craig Newland, *Australian Government Department of Transport and Regional Services, Australia*

Abstract:
A series of vehicle to pole lateral impact tests were conducted using ES-2 and WorldSID dummies. Pure lateral (90°) and oblique (75°) impacts were included in the test series and the level of protection offered by the head protecting side airbag was assessed under each condition.
The head injury risks predicted by the ES-2 and WorldSID dummies under the same oblique pole test conditions were dramatically different, with the ES-2 indicating a low risk of head injury and the WorldSID indicating a very high risk of head injury. Sled tests were used to investigate the kinematics of the ES-2 shoulder, the consequent influence of shoulder load on head/neck kinematics, and the ability of this dummy to discriminate the level of head protection offered by head protecting side airbags. The head, neck, and shoulder kinematics and peak shoulder loads of the ES-2 were found to be highly sensitive to the direction of loading to the shoulder resulting from each pole impact angle.

Paper No. 07-0319-O

Investigation Into The Effectiveness Of Advanced Driver Airbag Modules Designed For OOP Injury Mitigation

Jörg Hoffmann, Michael Freisinger, *Toyoda Gosei Europe N.V., Germany*
Michael Victor Blundell, Manoj Mahangare, *Faculty of Engineering and Computing, Coventry University, United Kingdom*
Peter Ritmeijer, *TNO Automotive Safety Solutions, The Netherlands*

Technical Session: Developments in Side and Frontal Impact Protection

Abstract:
In accordance with the NHTSA regulations for the protection of vehicle occupants from a deploying airbag with the FMVSS 208 standard, the development of frontal restraint systems is driven by new technologies and technical solutions to cover the challenging out-of-position (OoP) load case. Considering the subject of the driver airbags, traditional module technology addresses only the energy absorption capability to protect the driver occupant while in-position for a severe frontal crash load case. The early unfolding characteristics of the deploying airbag, and its physical effects on the environment were therefore not a part of the engineering focus at that time. This paper will discuss an advanced driver airbag module devised to deploy in an initially less aggressive mode, and therefore expose occupants seated OoP and close to the airbag's effective working area with less risk. The airbag inflation is divided into a primary and a secondary deployment phase by chambering the cushion with internal gas deflection fabric walls. After reaching an internal threshold pressure, these walls fail at a deterministic enervated split line. This leads to the full bag deployment to assure the energy absorption potential for the occupant seated in-position during the crash loading. This sophisticated deployment characteristic is simulated using a numerical approach to represent the actual fluid flow within the airbag reproducing the airbag's initial unfolding process. Initial simulations recreate a simple physical (pendulum) laboratory test scenario. Further consideration of the OoP performance of the advanced airbag module is provided by replacing the simple pendulum with the more complex digital female frontal dummy positioned in accordance with the FMVSS 208 standard. Finally the results found using the advanced airbag occupant simulation methodology are compared with the results from OoP occupant tests.

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Technical Session: Active/Passive Safety: Applying Integrated Solutions Along The Crash Timeline

Oral Presentations | Tuesday, June 19, 2007 | 8:30a.m.-1:00p.m.

Chairperson: John Hinch, USA | Track C | Room: Salon Pasteur
Co-Chairperson: Anders Lie, Sweden

Paper No. 07-0330-O

What Accident Analysis Tells About Safety Evaluations Of Passenger Vehicles - Contributions Of Primary And Secondary Safety To Overall Safety And Consequences For Safety Ratings

Robert Zobel, Torsten Strutz, *Volkswagen AG*
Joachim Scheef, *AUDI AG, Germany*

Abstract:
In the past, the overall safety of passenger vehicles was dominated by secondary safety features, the ability of vehicles to reduce the consequences of accidents by mitigating injuries. In the last ten years, crash avoidance devices that can reduce the likelihood of accidents were introduced into cars. These devices support the braking of drivers, such as brake assists, or they reduce the likelihood of skidding, such as ESC, others will follow. Accident research clearly and increasingly shows the effectiveness of such devices under European road conditions. Although road conditions in the U.S. are different, there are positive indications as well.
In Europe, for belted occupants, ESC-effectiveness is estimated to be higher than airbag effectiveness. The accident data, indicating this, have been consistent for a couple of years. This paper provides accident data predicting the amount of safety benefit to be attributed to the different safety features in terms of risk reduction. This might help to overcome the problem that current 4 and 5 star cars are said to be in fact better than cars with fewer stars, while there is no significant difference between 4 and 5 star cars in real world accidents. It is the goal of the paper to quantify the degree of the total safety, reflected by a crash test based rating, like the current rating in Europe.

Paper No. 07-0389-O

Analysis Of A Safe Road Transport System Model And Analysis Of Real-Life Crashes On The Interaction Between Human, Vehicle And Infrastructure

Helena Stigson, *Karolinska Institutet*
Maria Krafft, *Folksam Research and Karolinska Institutet*
Claes Tingvall, *Swedish Road Administration, Sweden*

Abstract:
The objective of this study was to evaluate if a simple model for a safe road transport system, include the human, the vehicle and the infrastructure could be used to optimise the components of the system.

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Real life crashes with fatal outcome were classified according to the vehicle active and passive safety system using EuroNCAP or Folksam car rating as well as active and driver supporting system. Furthermore the infrastructure with EuroRAP and human behaviour in terms of speeding, seat belt use and driving under the influence of alcohol for each crash were classified. The ideal situation was simulated, when all above factors were brought to what is expected in a safe system.

All fatal crashes with a killed car occupant occurring in Sweden during 2004 were included, in all 250 crashes. The data was collected through the in-depth crash system from the Swedish Road Administration.

Both the model as well as where the highest potential could be found in a system's perspective, could be given. In general, it was found that the impact severity was higher than the expected crash protection of a modern and safe vehicle.

By applying an integrated model of a safe system, both the model and the possible potentials are evaluated.

The future road transport system, considering the infrastructure, vehicle and the human, must be more compatible and more effectively in limiting the consequences of road crashes.

Partly subjective analysis of the crashes.

This study illustrates the interaction between human, vehicle and the infrastructure. Integrated crash studies are rare and the model has never been evaluated before.

Paper No. 07-0412-O

Definition Of A Pre-Crash Scenario Typology For Vehicle Safety Research

Wassim Najm, *Volpe Center*
David Smith, *National Highway Traffic Safety Administration, United States*

Abstract:
This paper defines a pre-crash scenario typology for light vehicles to establish a common foundation for vehicle safety research that enables public and private organizations to develop and estimate potential safety benefits of effective crash countermeasure systems. The accident type and pre-crash variables in the General Estimates System (GES) crash database allow the identification of pre-crash scenarios that portray vehicle movements and critical events leading to the crash. Derivation of the new typology was based on separate analyses conducted on single-vehicle, two-vehicle, and multi-vehicle (≥ 3) crashes. The first event in a crash was used to distinguish pre-crash scenarios in two- and multi-vehicle crashes. Based on 2004 GES data, this paper delineates a set of pre-crash scenarios by determining their frequency of occurrence and by statistically describing their contributing factors in terms of the driver, vehicle, and environment. In addition, a sample of 236 police crash reports were obtained to verify the

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representativeness of this set of pre-crash scenarios. This new typology will map all crashes involving at least one light vehicle, will be nationally representative, and can be annually updated using the GES. The analysis of the 2004 GES revealed a set of 36 dynamically-distinct pre-crash scenarios that describe what happened immediately prior to the crash. These scenarios represent 99.4% of all light-vehicle crashes, which accounted for approximately 5,942,000 police-reported crashes in 2004 in the United States. The sample of police crash reports was carefully reviewed and successfully mapped to this new pre-crash scenario typology. It should be noted that the new typology is based on police-reported crashes only, which may not completely reflect the frequency of occurrence of some of the scenarios. A novel typology of pre-crash scenarios is presented for vehicle safety research, which represents the majority of crashes based on data available from national crash databases.

Paper No. 07-0400-O

The TRACE Project: An Initiative To Update Accident Causation Issues And Evaluate The Safety Benefits Of Technologies

Yves Page, Thierry Hermitte, *Laboratory of Accidentology, Biomechanics and Studies of Human Behaviour - PSA RENAULT, France*

Abstract:

The Integrated Safety programme and the eSafety initiative stress that the development of Intelligent Transport Systems in vehicles or on roads (and especially in the safety field) must be preceded by a scientific accident analysis encompassing two main issues:

- The determination and the continuous up-dating of the aetiology, i.e. causes, of road accidents (as well as the causes of injuries) and the assesment of whether the existing technologies or the technologies under current development address the real needs of road users.

- The identification and the assessment (in terms of lives saved and accidents avoided) of the most promising solutions that can assist the driver or any other road users in a normal road situation or in an emergency situation or, as a last resort, mitigate the violence of crashes and protect vehicle occupants, pedestrians, and two-wheelers in case of a crash or a rollover.

The objective of the TRACE project (TRaffic Accident Causation in Europe) is to provide the scientific community, the stakeholders, the suppliers, the vehicle industry and the other Integrated Safety program participants with a global overview of the road accident causation issues in Europe, and possibly overseas, based on the analysis of any and all current available databases which include accident, injury, insurance, medical and exposure data (including driver behavior in normal driving conditions). The idea is to identify, characterise and quantify the nature of risk factors, groups at risk, specific conflict driving situations and accident situations; and to estimate the safety benefits of a selection of technology-based safety functions. Expected outcomes are essentially reports

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TRACE proposes three different research angles for the definition of accident causation factors, and also proposes to improve the methods actually used in accident analysis. And finally, TRACE intends to base the analyses on available, reliable and accessible existing and on-going databases (access to which will be greatly facilitated by a series of partners highly experienced in safety analysis, coming from 8 different countries and having access to different kinds of databases, in-depth or regional or national statistics in their own country, and for some of them in additional countries).

Paper No. 07-0064-O

Influence Of Road Characteristics On Traffic Safety

Sarbaz Othman, Robert Thomson, *Chalmers University of Technology - Applied Mechanics, Sweden*

Abstract

The objective of this research is to investigate and analyze the effects of the road geometric characteristics and road condition on the accident rate of the highway and semi-highway roads in the Western region of Sweden. The study was based on accident data and road maintenance data. All accidents with person injury occurred during a 6 years period (2000 – 2005) on 1615 km median separated roads have been examined. A total of 2912 accidents with person injury have been collected and combined with road characteristics data (Speed, number and width of lanes, AADT, vertical and horizontal alignments, super elevation). Including 54 fatalities 294 sever injuries and 3877 light injuries. The study was carried out in four phases. 1- Collecting and analyzing accident data from different databases, 2- Collecting road condition and characteristics data, 3- Combining the data of the two previous stages, 4- Analyzing combined data statistically to locate and identify black spots.

The statistical analysis shows how the curve radius of bends, road surface state, and other road characteristics are important factors of influence on the traffic safety. Furthermore it provides additional information on how wet and thin ice road surfaces effect on accident rates.

The investigation offers a new approach for the influence of road characteristics on accident rate, which can be used as an input for future ABS (Antilock Braking System) and ESP (Electronic Stability Program) system designs.

Paper No. 07-0207-O

Real World Experience With Advanced Air Bags

Eric Ferguson, John Brophy, John Kindelberger, Greg Radja, *National Highway Traffic Safety Administration, United States*

Abstract:

The National Center for Statistics and Analysis's (NCSA), Special Crash Investigations (SCI) program, provides the National Highway Traffic Safety Administration with an anecdotal data set that allows the agency to analyze in depth clinical evaluations of real-world crashes that involve new and emerging

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technologies. One of SCI's responsibilities is to investigate alleged fatalities that are related to the deployment of an air bag in minor to moderate severity crashes. The first part of this paper will compare the number of occupants fatally injured by a deploying air bag for either a given model year or a 12-month release period, to the number of air bag equipped vehicles in the corresponding fleet. In this paper advanced air bags are defined as air bag systems with one or more advanced occupant protection features such as: multi-stage inflators, safety belt sensors, weight sensors, seat position sensors, and automatic suppression systems. The fatality rates for occupants injured by advanced air bags will be compared to those injured by pre-advanced air bags. Based on our most recent observations the fatality rates associated with advanced air bags are expected to be lower than that for pre-advanced air bags. An overview of the only published advanced air bag related fatality case will be provided.

NCSA's National Automotive Sampling System Crashworthiness Data System (NASS CDS) collects data on representative crashes through 27 field research teams that investigate about 4500 crashes a year. The second part of this paper will analyze SCI and NASS CDS advanced air bag data through the end of 2005. A variety of advanced air bag related topics for front seat occupants will be discussed. Crash severity, weight sensors and air bag deployment stages will also be discussed.

Paper No. 07-0183-O

Objective Test Scenarios For Integrated Vehicle-Based Safety Systems

Wassim Najm, *Volpe National Transportation Systems Center*
Jack Ference, *National Highway Traffic Safety Administration*
Sandor Szabo, *National Institute of Standards and Technology, United States*

Abstract:
This paper presents a set of crash-imminent test scenarios to objectively verify the performance of integrated vehicle-based safety systems designed to address rear-end, lane change, and run-off-road crashes for light vehicles and heavy trucks. National crash databases are analyzed to identify applicable pre-crash scenarios as a basis for the development of objective test scenarios, and to determine dominant crash characteristics as initial conditions for the test scenarios. In addition, practical considerations are assessed based on established test procedures for individual crash avoidance systems.
Crash analyses are conducted on the 2003 General Estimates System (GES) crash database for light vehicles and the 2000-2003 GES databases for heavy trucks. Prior documentations on system objective testing from NHTSA sponsored projects and international standard organizations are also reviewed. This paper will prioritize pre-crash scenarios in terms of their frequency of occurrence and highlight their most relevant characteristics. Potential test scenarios will be presented for rear-end, lane change, run-off-road, and integrated system functions.
This paper will illustrate practical test scenarios for light vehicles and heavy trucks including the actual dynamic scenario, initial condition variations, set up, and measures of performance. Time and cost constraints, safety considerations, physical limitations of the vehicle-driver system, environmental

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conditions, performance metrics, instrumentation, and pass-fail criteria on test tracks will also be discussed.

Paper No. 07-0103-O

Real World Safety Benefits Of Brake Assistance Systems

Joerg Breuer, Stefan Gleissner, Andreas Faulhaber, Peter Frank, *DaimlerChrysler AG, Germany*

Abstract

The European Commission has set an ambitious goal for road safety in Europe: The road safety action programme aims at reducing the number of fatalities by 50% in the period from 2000 to 2010. The interim result for Germany is promising: Between 2000 and 2005, the number of fatalities was reduced by 29% in spite of a fleet increase of 6%. The last decade has seen a decrease in fatalities of 43% in Germany. While these improvements can be attributed to a variety of factors, advanced vehicle safety technology certainly plays a major role.

Having addressed the problem of loss of control-accidents most successfully by the introduction of ESP® as a standard feature in all passenger vehicles, Mercedes-Benz safety engineering now focuses on avoiding and mitigating rear-end crashes. The first brake assist system (BAS) was developed by Mercedes-Benz and first introduced in 1996. It has been a standard feature on all Mercedes-Benz passenger cars since 1997. Recent statistical analyses of German accident data show significant safety benefits of this technology: Both the percentage of severe accidents involving pedestrians as well as the rate of rear end collisions are lower for vehicles equipped with BAS (13% and 8% respectively) than vehicles without BAS.

The package consisting of adaptive brake lights and conventional brake assist (BAS) is now completed by radar based intelligent brake assistance (BAS PLUS and PRE-SAFE® Brake). Function and safety benefits of these advanced assistance systems are described and an outlook into the near future is given.

Paper No. 07-0450-O

Collision Warning With Auto Brake – A Real-Life Safety Perspective

Erik Coelingh, Lotta Jakobsson, Henrik Lind, Magdalena Lindman,*Volvo Car Corporation, Sweden*

Abstract:

Automotive safety has gained an increasing amount of interest from the general public, governments and the car industry and traffic accident statistics more than justify this focus, as each year around 1.2 million people die due to road traffic accidents. For these reasons safety remains a core value of Volvo. This paper presents some the latest active safety developments within Volvo Car Corporation and describes how this impacts real-life safety.

Rear-end collisions are common accident scenarios. A common cause of these accidents is driver distraction and thus not reacting in time. No vehicle system is a substitute for the most important safety

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feature in any vehicle: the driver. However, Volvo is harnessing innovative technologies to help alert drivers to avoid potential collisions and reduce the potential impact speed when a collision cannot be avoided.

Collision Warning with Auto Brake - The area in front of the car is continuously monitored with the help of a long-range radar and a forward-sensing wide-angle camera fitted in front of the interior rear-view mirror. A warning and brake support will be provided as above, both for moving and stationary vehicles. Additionally, if the driver does not intervene in spite of the warning and the possible collision is about 0.7 seconds ahead, i.e. the collision threat becomes imminent, intervention braking is automatically applied to slow down the car. In this way it may not be possible to avoid a collision, but the main purpose here is to reduce impact speed and the risk of consequences.

These systems has been verified using innovative CAE methods and practical tests and will be launched in the near future. Finally, it is discussed how the benefit of this system can be judged from real-life safety perspective using accident statistics.

Paper No. 07-0155-O

Development Of Objective Tests For Evaluating Lane-Keeping/Road Departure Driver Assistance Systems

August Burgett, Raja Ranganathan, Gowrishankar Srinivasan, *URC Enterprises, Inc., United States*

Abstract

This paper describes a step-by-step process for the development of test procedures for pre-production driver assistance systems. The process begins with a detailed engineering description of system performance and ends with a set of objectives test procedures that can be applied to pre-production driver assistance systems. The process utilizes an universal description of the causal factors and resulting crash types as the foundation for a detailed analysis of crash data. Factors such as trafficway flow, alignment, curvature and speed are also analyzed to determine appropriate test conditions.
The process is applied to the task of establishing test procedures for systems that address lane-keeping/road departure related crashes. The basis for the analysis is data from the 2004 GES and 2004 FARS national crash databases. There were 10,945,000 vehicles involved in crashes in the United States in 2004; of which 1,114,000 and 977,000 vehicles were involved in multi and single-vehicle lane-keeping/road-departure type crashes, respectively. The results of the analysis led to separate tests for single and multi-vehicle crashes. Single vehicle crashes are represented by two types of tests: first, a test on a curved two-lane undivided highway with a narrow shoulder; and second, a test on a multi-lane undivided highway with a parked vehicle on the shoulder. The multi-vehicle crashes involve testing vehicles traveling in the same direction and in opposite directions. For example, tests of vehicles traveling in the same direction include straight undivided multi-lane roads with the vehicle approaching a lane demarcation at a 3 degree angle.

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This is the initial application of a new crash-analysis-based process for developing test procedures. Additional challenges in performing the tests, and using the results to estimate crash avoidance benefits, are not discussed in detail in this paper.

Paper No. 07-0398-O

Crash Risks Assessment On Road Curves

Samantha Chen, Andry Rakotonirainy, *Centre for Accident Research and Road Safety Queensland University of Technology*
Seng Wai Loke, *La Trobe University*
Shonali Krishnaswamy, *Monash University, Australia*

Abstract:
A comprehensive model to assess crash risk and reduce driver's risk exposure on road curves is still unavailable. We aim to create a model that can assist a driver to negotiate a road curve safely with Intelligent Transport System technologies. This paper presents a conceptual framework which uses situation awareness, ubiquitous data mining and driver behaviour modelling concepts to assess crash risks on road curves. Sensors are used to collect real time information about the driving context. The driving context consists of the environment, driver and vehicle dynamics. Data from sensors can be unreliable, inaccurate or incomplete. The driving context information is augmented with crash patterns of past crashes from crash databases from an insurance company. We perform ubiquitous data mining to analyse the combined data to obtain crash patterns. Ubiquitous data mining is a process to extract patterns on mobile devices that have limited resources in real-time. The patterns are used to train a driver graphical model: Coupled Hidden Markov Model, which learns, classifies information into different categories and predicts possible driver behaviour which are based on calculated probabilities. Crash risks are assessed using the predictions and a risk assessment scale that is created based on driver behaviours on road curves. This research defines a novel statistical model that assesses risks for curve-related crashes using ubiquitous data mining by integrating information about the driving context and past crash data to reduce drivers' risk exposure. Hence, this could potentially reduce curve related crashes.

Paper No. 07-0479-O

Active/Passive Safety: Applying Integrated Solutions To Rollover Crashes

Craig Kloeden, Jack McLean, Giulio Ponte, *University of Adelaide, Australia*

Abstract:
Rollover crashes are investigated to identify ways in which active and passive safety solutions might be applied most effectively. Results of at-scene investigations of rural crashes by a research team and police reports of all crashes are reviewed. 236 crashes to which an ambulance was called, including 64 rollover cases, were investigated in the at-scene study, conducted on rural roads in South Australia. During a similar period police reports were compiled on 163,578 crashes, including 2,653 rollover cases. Injuries were sustained in 50% of the rollover cases but in only 18% of all other reported crashes (crashes

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resulting in a casualty or property damage of more than $1,000 were required to be reported). About half of the single vehicle rollover crashes in both studies occurred on straight roads; in the at-scene study after the vehicle drifted onto the unsealed shoulder. In every such case the vehicle yawed out of control before rolling. This is illustrated by photographs of the yaw marks and the final position of the vehicles, together with scale plans of these vehicle motions. The percentage of crashes which resulted in rollover increased with the posted speed limit: 5% at 80 km/h to 31% at 110 km/h. Vehicle factors relevant to crash and injury causation are also addressed. Combining information from these two studies overcomes to some extent their individual limitations, of small sample size in one instance and less detailed data in the other. These studies illustrate, among other matters, the type and frequency of situations in which stability control can be expected to prevent rollover crashes in a region where the roads are rarely wet, together with the importance of limiting travelling speed.

Paper No. 07-0362-O

A Realistic Crash Test Setup To Assess The Real World Performance Of Advanced Rollover Sensing Systems

Alexander Berg, Peter Rücker, *DEKRA Automobil GmbH*
Mario Kröninger, *Robert Bosch GmbH, Germany*

Abstract:
To protect occupants during a rollover event, restraint control modules with integrated Rollover Sensing (RoSe) function have been developed. These devices are able to trigger belt tensioners and curtain airbags if the vehicles' roll angle and roll rate indicate that the vehicle is going to tip over. Especially in the case of tripped rollovers, however, the optimum trigger time for curtain airbags is before the vehicle has build up a significant roll angle. To cope with this challenge Bosch's advanced rollover sensing function uses the lateral velocity of the vehicle as additional input to it's deployment decision.
Based on a new rollover crash test setup developed by DEKRA the performance benefit of this advanced rollover sensing system can be shown under realistic circumstances. The test does not only cover the rollover phase but also the skidding phase before the vehicle enters the soil and rolls over. Fist tests have been performed to investigate in both the repeatability of the movement and the behaviour of the vehicle during such a test. To steer the car, an optically controlled guidance is used combined with a time-based activation of the steering. The vehicle runs on a my-split path. Several sensors are used to measure the relevant kinematics (velocity, acceleration, yaw-, roll- and pitch-rate). Additionally the movement is filmed by several high-speed cameras.
With the article the authors show the test method and the results and discuss the benefit of this new method to assess the performance of an algorithm for advanced rollover protection.

Paper No. 07-0165-O

Multi-sensor Driver Monitoring System Using State-of-the-Art Signal Modelling

Memis Acar, Pinar Boyraz, David Kerr, *Loughborough University, United Kingdom*

Technical Session: Active/Passive Safety: Applying Integrated Solutions Along The Crash Timeline

Abstract
This study presents a proposed solution to driver performance monitoring combining inexpensive and non-intrusive sensors together with the state-of-the-art signal processing techniques, probabilistic theory and artificial intelligence for signal analysis and modelling. In order to investigate the extent of the solution, a highway scenario simulator experiment was conducted, using 30 volunteer drivers in normal physical conditions and also when impaired due to lack of sleep. The simulator was equipped with a near-infrared eye-gaze tracker, strain gauges to measure force on the steering wheel column (SWC), and potentiometers to measure steering wheel and throttle angle. In addition to these core sensors, two webcams were implemented to view the driver and to track lane-keeping. Raw data were obtained comprising eye movement, force on SWC, vehicle speed, lane deviation, and human activity from the webcam. The data were first processed up to a level where all signals were 1-D and continuous. Secondly, using derivatives, histograms and entropies of the signals, metrics were derived. These metrics were then tested against a ground truth risk level obtained from a driver survey and from independent observers. After selecting the best metrics for driver performance indication, different time windows for metric derivation were compared and the driver sessions were classified by two different algorithms: a Fuzzy Inference System and Artificial Neural Networks. The system worked well on the simulator data, with a 98% correct classification rate and is now being implemented in real conditions on real roads.

Paper No. 07- 0010-O
Vehicle Safety Communications In The USA
Michael Shulman, *Ford Motor*
Richard Deering, *General Motors, United States*

Abstract:
In the United States, passenger vehicle manufacturers have been working together, along with the U. S. government, to study wireless communications for vehicle safety applications.

From 2002-4, seven automotive manufacturers—BMW, DaimlerChrysler, Ford, GM, Nissan, Toyota, and VW— worked with the National Highway Traffic Safety Administration (NHTSA) to evaluate vehicle safety applications enabled or enhanced by communications. This project determined initial communication requirements for each application, performed some Dedicated Short Range Communications (DSRC) vehicle testing and helped to develop the DSRC standards so that the requirements of the safety applications were considered. The project identified eight scenarios as high-priority and selected for further research based on the estimated potential safety benefits. Of these eight application scenarios, four involved vehicle-to-vehicle (V-V) communications and four involved communications between vehicles and the infrastructure. Three of the vehicle-infrastructure communication applications involved intersections.

From 2005-6, BMW, DaimlerChrysler, Ford, GM, Nissan and Toyota decided to develop and evaluate the Emergency Electronic Brake Light application (EEBL) as the first vehicle-to-vehicle cooperative active safety application in order to:

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Develop concepts of operation, system and communication requirements
Establish a common V-V EEBL message set and demonstrate interoperability
Define & perform common engineering tests to conduct preliminary benefits assessment
Report to the industry on results
Guide future V-V safety applications development

In 2006, DaimlerChrysler, Ford, GM, Honda and Toyota initiated two major vehicle safety communications projects with the NHTSA and the Federal Highway Administration. The first project is developing and field testing a cooperative infrastructure-to-vehicle safety application to address intersection crashes. The second project, Vehicle Safety Communications Applications, will develop acommon vehicle safety communication architecture, protocols and messaging framework necessary to achieve interoperability and cohesiveness among different vehicle manufacturer's applications and an analysis of potential benefits versus market penetration for vehicle safety communications applications.

Paper No. 07-0062-O

Development Of Technical Guidelines For Visual Drive Recorders (VDR)

Hidenobu Kubota, Toshihiko Kude, *Ministry of Land, Infrastructure and Transport*
Yasushi Yokoya*, Japan Automobile Research Institute, Japan*

Abstract

In 2006, Transport Policy Council, an advisory group of Japan Ministry of Land, Infrastructure and Transport (JMLIT) consisting of vehicle safety experts, submitted a report on future vehicle safety measures to the Minister of JMLIT.

The projections in this report indicate that the number of traffic fatalities and injuries will dramatically decrease until 2010. The report also sets gzero fatalities h as the ultimate target.

To achieve this aim, however, it is necessary to identify and promote new active safety measures. Therefore, near-miss situation data as well as accident data, which would be recorded by an on-board VDR, should be analyzed and evaluated.

In October 2006, JMLIT organized a panel of experts to discuss and develop technical guidelines for such VDRs.

Paper No. 07-0203-O

The Correlation Between JNCAP Pedestrian Head Protection Performance Test and Real-World Accidents

Kei Takeuchi, *Japan Automobile Research Institute*
Takahiro Ikari, *National Agency for Automotive Safety & Victims' Aid, Planning Department, Japan*

Abstract:

The Pedestrian head protection performance tests were introduced to Japan New Car Assessment Program (JNCAP) in 2003. In the test, a head impactor of an adult or a child is projected toward the car bonnet, front windshield and etc., and head injury criterion (HIC) is measured. The aim of this study is to

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investigate the correlation between head protection performance test results and injury severity of pedestrian in real-world accidents.
56 models of passenger cars tested in JNCAP from 2003 to 2005 are examined. In JNCAP test, head protection performance score was evaluated from 0 to 4 (continuous number) and also evaluated as a level 1 to 5 (discrete number). We limited the accidents where pedestrians are hit by the car models identical to the cars in JNCAP tests. We defined fatal/severe injury rate (the ratio of fatal or severe injury driver in all accidents) of pedestrians as an index of risk of pedestrian in the accident. The national accident data (police data) in Japan obtained from ITARDA are used and accident investigation area is whole Japan. The sample size of the data was approximately 4,000 and the accidents were occurred from 2002 to 2005.
The logistic regression method is applied to adjust confounding factors, such as gender and age of the pedestrian and day or night of the accident. As a result of the study, we saw that, although the sample size is not statistically enough, the pedestrian head protection performance improvement would contribute to reduce the pedestrian fatality/severity in real-world accidents.

Paper No. 07-0075-O

Correlation Between JNCAP Braking Performance Tests And Real-World Accidents

Kei Takeuchi, *Japan Automobile Research Institute*
Yuji Ono*, National Agency for Automotive Safety & Victims' Aid, Japan*

Abstract
The brake performance test was first introduced to the world in 1995 at Japan New Car Assessment Program (JNCAP). In the test, stopping distances from a speed of 100km/h on dry and wet surfaces are measured. It may be expected that shorter stopping-distance cars show better performance in avoiding crashes, or if they cannot avoid them, resulting in diminishing injury severity owing to reduced impact speed. The study focuses on the correlation between JNCAP brake test and the effect of diminishing injury severity in real-world accidents.
The national accident data in Japan are used for the study. The accident investigation period was set between 1998 and 2003 for 87 models of passenger cars tested in JNCAP from 2000 to 2003. The number of accidents (drivers) on dry road was 58,640 and that on wet road was 15,166. Fatal/severe injury rate (number of fatal or severely injured drivers divided by number of all drivers involved in the accidents) are compared between the cars.
The logistic regression method is applied to adjust two confounding factors, crashworthiness score of cars evaluated in JNCAP and accident year. On dry road, estimated odds ratio of brake performance on dry road is 1.058 (95% C.I.: 1.014, 1.104) and estimated odds ratio of brake performance on wet road is 1.034 (95% C.I. : 0.998, 1.071). Odds ratio can be interpreted as if there is a 1m increase in stopping distance in the test, the average fatal/severe injury rate is increased by the odds ratio. It seems to suggest that shorter stopping-distance cars contribute to reduce the injury severity in real-world accidents.

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Technical Session: Vehicle Handling Stability and Control Systems and Rollover Prevention

Oral Presentations | Tuesday, June 19, 2007 | 2:00p.m.-5:30p.m.

Chairperson: Thomas Breitling, Germany | Track B | Room: Amphitheatre Pasteur
Co-Chairperson: Catherine Lovell, UK

Paper No. 07-0136-O
Roll-Rate Based Roll Stability Control System
Jianbo Lu, Dave Messih, Albert Salib, *Ford Motor Company, United States*

Abstract:
This paper presents the Roll Stability Control (RSC) system developed at Ford. RSC is an active safety system, namely, a bake control system to achieve anti-rollover function. It uses a roll rate sensor together with the conventional ESC sensor set to sense the vehicle's states, controls the brake actuators and requests engine torque reduction to achieve rollover mitigation. The vehicle state estimation algorithms include calculations for global roll angle, chassis roll angle, road bank, and wheel departure angle from the road. These states are then used in both feedback and feedforward control, generating actuator commands through control algorithms. This paper provides a brief description about the vehicle's roll sensing and control strategies. Vehicle test results will be used to show the effectiveness of RSC. A simulation comparison between Ford's RSC and a rollover mitigation system utilizing an enhanced ESC system (without using roll rate) is also conducted.

Paper No. 07-0138-O
Enhancement Of Car Safety Using Improved ESC And Tyre Development Method
Fenaux Eric, *PSA Peugeot Citroen*
Buisson Jeremy, *MICHELIN, France*

Abstract:
ESC efficiency to reduce accident is now well proven. To obtain this accident reduction tests employed for the tuning of a car equipped with an ESC must be related to real world accident cases. With accident statistics obtained in France, two main categories of accidents are defined : loss of control in a curve and accidents in a straight line or at an intersection. For each of these categories, thanks to detailed analyses of real accidents, we can define tests scenarios that are related to real world. Several examples are given.

To measure the performance of a car equipped with an ESC during these tests, stability criteria are defined. In addition criteria to assess the quality of ESC intervention are defined. These tests pointed some limitations of ESCs. Some improvements of ESCs algorithms were specified to overcome these problems. Examples are given.

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During this ESC tuning, it is decided if a rollover prevention module is necessary or not. This decision process, that includes both real tests and HIL (Hardware In the Loop) tests is described. One of the conditions that may lead to a rollover is a contact between the rim and the ground. This process also enables us to define test conditions to check there is no risk of rim contact on the ground.

A test method of a tyre on a bench to check these conditions are satisfied is described. It is also shown that the risk to have a contact of the rim on the ground is not significantly modified during the brake activation by the ESC.

Paper No. 07-0142-O

Effects Of The Process Of Rear Tire Delamination On Vehicle Stability

David Renfroe, Alex Roberts, David Beltran, *Engineering Institute, LLC., United States*

Abstract:

The effects of the delaminated tire on the handling of a vehicle has been well documented, however, the period when the tire is delaminating, which can last from one to many seconds, can pose a serious threat to vehicle stability depending on the duration of the delamination process, the design of the rear suspension of the vehicle, and the speed at which the delamination commences. This paper will present the results of testing where a delaminating tire causes a bump on the tire and the vehicles lost control even with expert drivers. Then these same vehicles were tested under a controlled environment to determine that the cause of the loss of control is axle tramp induced by the bump frequency of the delaminating occurring at the natural frequency of the axle/spring system. During this tramping the handling characteristics become severely oversteer. The resulting oversteer has been measured using standard SAE J266 test procedures for two models of SUV's and two models of 15 passenger vans. Proposed solutions were increasing the tramp damping characteristics of the axle system and/or the addition of dual wheels on the 15 passenger vans. These solutions are examined for their effectiveness. Testing will illustrate how proper shock absorber sizing and placement will allow the maintenance of a positive understeer gradient even during a high speed delamination event.

Paper No. 07-0432-O

Behaviour Of SUV And MPV-Type Vehicles In Collisions With Roadside Safety Barriers

Roy Minton, Richard Cuerden, *TRL Limited, United Kingdom*

Abstract:

Roadside safety barriers are designed to deflect errant vehicles back onto the carriageway, preventing them from encountering potentially dangerous off-road hazards or crossing into the opposing carriageway on dual carriageways. However, there are concerns that SUVs and MPVs, by virtue of their greater mass and height, may not be well catered for by the current design of safety barrier, which is tested to withstand an impact with a 1500kg standard car.

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An analysis of National accident statistics (all police-reported injury accidents in Great Britain) is presented, which indicates that the occupants of these larger vehicles generally incur less severe injuries than occupants of standard cars. Only a small proportion of road accidents involve barrier strikes, and the involvement of a barrier is associated with increased likelihood of rollover and increased injury severity for occupants of all vehicle types. These increases in rollover incidence and injury severity are found to affect SUVs and MPVs much more than standard cars (rollover incidence rises by factors of 4 for cars, 7 for SUVs and 9 for MPVs).

However, detailed information on a small number of barrier strike accidents involving SUVs or MPVs taken from TRL's in-depth accident databases (24 cases in total) indicates that the barriers themselves may not be to blame. The barriers are found to exceed their design specification in a number of cases, and the cause of the accident is found in several cases to be difficulty in controlling these larger vehicles in extreme situations.

Despite the limitations of a lack of detail in the national accident statistics and a small number of cases for in-depth analysis, this study nevertheless offers a useful insight into an accident scenario in which SUVs and MPVs become less safe for their own occupants than standard cars.

Paper No. 07-0269-O

Light Commercial Vehicles – Challenges For Vehicle Stability Control

Edwin Liebemann, Thomas Fuehrer, Patrick Kroeger, *Bosch, Germany*

Abstract:

The electronic stability program (ESP®) is increasingly finding acceptance in vans. Nearly all current models, whose gross vehicle weight is generally between 2.8 and 7.5 metric tons, are now available with this active safety system, either as an option or even as standard equipment. Many studies have now confirmed that ESP® can prevent a vehicle from skidding or rolling over in nearly all driving situations. This is particularly important in the case of vans, since their design and their use leave them with tighter safety margins. Depending on load, the center of gravity shifts, and consequently the risk of rollover may increase. Bosch has developed a system specifically for light commercial vehicles that automatically adapts its control mechanisms to the current situation.

Paper No. 07-0444-O

Lateral Accelerations On Heavy Trucks --- Contribution From Wind Forces

Frank Wilson, Eric Hildebrand, *University of New Brunswick, Canada*

Abstract:

A 5-axle tractor-trailer unit was evaluated under actual road conditions as it travelled around two highway ramps of different radi while being subjected to a range of wind conditions.A mobile data acquistion system (DAS) was designed and mounted in the vehicle which measured speed, lateral accelerations, and roll angle of the trailer . Wind conditions (speed and direction)were measured using a portable wind station positioned adjacent to the ramp. The data were

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correlated with the DAS.The wind speed and direction were measured at one second intervals.The DAS recorded data from three triaxial accelerometers which measured the lateral ,vertical and longitudinal accelerations while the vehicle was in motion.One acclerromrter was placed at the fifth wheel, one in the cab and one at the top of the rear of the trailer.The roll angle indicator was placed at the top of the trailer at the rear along the centerline.The DAS collected data at 1/5 second intervals. The data base contained 50 observations on both curves 1 & 2. The wind speeds were clustered in three ranges and the vehicle speeds were separated into three categories. The results were submitted to a test of significane analysis and found to be significant in all categories.The results delinated the increase in lateral accelarations as the vehicle encountered increased wind speeds. In several cases the forces exceeded the roll threashold for the vehicle but the duration was short and did not cause roolover. The field experiments confirmed that the equipment was capable of recording actual field conditions for a range of wind levels. The data could be used to evaluate speed advisory signing for ramps and testing of vehicle rollover warning systems.

Paper No. 07-0184-O

Real-World Assessment Of Relative Crash Involvement Rates Of Cars Equipped With Electronic Stability Control

Pete Thomas, Richard Frampton, *Loughborough University, United Kingdom*

Abstract:

This paper uses the national accident statistics of Great Britain to evaluate the effectiveness of Electronic Stability Control Systems (ESC) to reduce crash involvement rates. The crash experience of 8951 cars is analysed and compared to a closely matching set of non-ESC cars using case-control methods. This is one of the largest ESC samples analysed to date. Overall the cars with ESC are involved in 3% fewer crashes although the effectiveness is substantially higher under conditions of adverse road friction. ESC equipped cars are involved in 15% fewer fatal crashes although this reduction represents the combined effect of ESC and passive safety improvements.

Overall cars equipped with ESC were involved in 3% fewer crashes representing a reduction of around 9,000 crashes if all cars in GB were equipped with ESC. On dry and wet road surfaces the effectiveness was 2% and 4% but on snow or icy roads ESC equipped cars were involved in 25% fewer crashes. On urban roads cars with ESC had a 1% higher accident involvement rate while on rural roads crashes

ESC equipped cars were involved in 6% fewer crashes and this increased to 16% fewer crashes on motorways. Male drivers of cars with ESC experienced a 5% lower rate of crashes compared to their non-ESC male counterparts. Female drivers on the other hand showed a non-significant 1% increase of crashes. The accident data showed cars with ESC were involved in 20% fewer skidding related crashes although it has to be considered that these cars will almost uniformly also be equipped with ABS. Overturning crashes were 50% lower.

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Using standard accident costs the reduction in crashes would represent a total saving of over £500,000,000 if ESC were fitted to the entire UK fleet.

Paper No. 07-0230-O

Objective Test Methods To Assess Active Safety Benefits Of ESP

Marcus Nuessle, Ruediger Rutz, Matthias Leucht, Markus Nonnenmacher, Hardy Volk, *DaimlerChrysler, Germany*

Abstract:

Since ABS started in the Mercedes-Benz S-class (W116) in 1978, but mainly by the introduction of ESP in 1995 in the Mercedes-Benz S-class (W140), Active Safety of passenger cars has been affected by combination of chassis parameters and wheel-brake based systems. Since ESP has a significant impact on vehicle stability the evaluation of Active Safety has to be performed in combination with ESP. Therefore objective test have been developed to assess the combination of chassis and ESP. A huge number of tests is used during the development and application of ESP Systems to vehicle platforms. Many accidentology investigations showed an outstanding benefit of ESP for Active Safety. This raised the interest in objective test methods to assess ESP performance and finally leads to NHTSA's recently published notice of proposed rulemaking for safety standards for ESP.

This paper will demonstrate various objective tests and measures for ESP evaluation. This article will illustrate objective criteria by means of ESP sub-functions and several operating points (e.g. different speed, lateral acceleration, steering input). The objective behaviour of ESP on high µ will be discussed as well as special demands on low µ.

The next steps on the roadmap of Active Safety are based on radar systems. These systems are "looking further ahead" to prevent accidents by aiding the driver. Today, already at market introduction of new Active Safety systems, like BAS Plus and PRE-SAFE break, objective measures of their performance are published.

Paper No. 07-0456-O

Light Vehicle ESC Performance Test Development

Garrick Forkenbrock, Patrick L Boyd, *National Highway Traffic Safety Administration, United States*

Abstract:

On September 14, 2006 the National Highway Traffic Safety Administration (NHTSA) announced a proposal that would require installation of electronic stability control (ESC) as standard equipment on all light vehicles by model year 2012. Mandating ESC requires NHTSA develop an ESC compliance test and evaluation criteria. This paper describes the test maneuver and the methods used to interpret the data.

The research described in this paper used test data from 62 vehicles, and 128 vehicle configurations. These data were collaboratively collected by NHTSA's Vehicle Research and Test Center (VRTC) and eleven vehicle manufacturers. Tests were performed with ESC fully enabled, fully disabled, and partially disabled where applicable.

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The authors recommend NHTSA use the Sine with Dwell maneuver to evaluate the lateral stability and responsiveness of ESC-equipped light vehicles. This maneuver is based on a single cycle, 0.7 Hz steering input, with a 500 ms pause between the third and fourth quarter cycles.

In order for the lateral stability of a vehicle to be deemed acceptable, the authors recommend two performance criteria, intended to encourage yaw rate to decay in a controlled manner, be satisfied. This is accomplished by comparing the yaw rates measured 1.0 and 1.75 seconds after initiation of the maneuver's steering inputs to the first local yaw rate peak produced after the second steering reversal. The authors propose the yaw rate ratios calculated at these two instants in time be less than or equal to 35 and 20 percent, respectively.

To ensure a balance between lateral stability and the ability for the vehicle to respond to the driver's inputs, the authors believes a responsiveness metric must supplement any criteria intended to only evaluate lateral stability. The authors recommend this be accomplished via use of "Unacceptable Zone" of performance that requires Sine with Dwell steering wheel angles 180 degrees or more to produce a minimum lateral displacement of 6.0 ft, calculated via the double integration of lateral acceleration 1.071 seconds after initiation of the maneuver's steering inputs.

Note that ESC systems are designed to mitigate excessive over- and understeer. However, the Sine with Dwell maneuver and performance criteria described in this paper were specifically developed to facilitate the evaluation of excessive oversteer only. NHTSA is presently performing ESC understeer mitigation research; however results from these tests are not yet available.

Paper No. 07-0501-O

A Repeatability Examination Of NHTSA's Proposed FMVSS 126 ESC Evaluation Method And Metrics

John Carriere, *General Motors*
Gene Lukianov, *DaimlerChrysler*
Ken Boyd, *Ford, United States*

Abstract:
NHTSA's proposed FMVSS 126 ESC evaluation method and performance requirements are repeatedly tested by three Manufacturers (and NHTSA) using two vehicles, five locations and three temperature ranges. The results are examined to determine variability due to location and temperature variations. Conclusions are presented on the variation of observed results.

Paper No. 07-0217-O

Quantitative Measure Of Transient Oversteer

David Renfroe, Alex Roberts, Paul T. Semones, *Engineering Institute, LLC, United States*

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Abstract:
When discussing oversteer of a vehicle, reference is made to results of the SAE J266 circle test or gradually increasing steer test. However, these are the vehicle's characteristics at quasi-static conditions and does not consider the dynamic effects of the moment of inertia of the vehicle or of the wheelbase during yaw accelerations occurring in transient maneuvers. Frequently, there are discussions of the transitional effects on oversteering of the vehicle and reference may be made to the radius of gyration squared versus the product of the front and rear distances from the axles to the CG. This particular relationship however, assumes that the tire lateral capabilities on the front and the rear are the same. This paper will discuss the comparison of the "Ackermann yaw rate" versus the measured yaw rate in transient steer maneuvers such as the step steer. The Ackermann yaw rate will be the yaw rate developed if the vehicle were to track exactly along the direction that the wheels are pointing. If this theoretical yaw rate is compared to the measured yaw rate, a vehicle's transitional handling characteristics can be quantified. An example where there has been considerable discussion is with the 15 passenger van. Loss of control these vans attributed to oversteer when attempting an accident avoidance maneuver has been discussed extensively from government and private groups. That oversteer occurs even though these vans exhibit understeering characteristics when tested with the J266 protocol up to a transition to oversteer at 0.75 g's. The technique described here allows the transitional oversteer characteristic of this van to be quantified and compared to a modified van that did not exhibit this transient oversteer. This will help to explain and quantify the characteristic causing the loss of control of the vans and other similar vehicles.

Paper No. 07-0495-O

Lane Departure Warning System Research And Test Development

Frank Barickman, *National Highway Transportation Safety Administration*
Robert Jones, Larry Smith, *Transportation Research Center, Inc., United States*

Abstract:
According to Traffic Safety Facts 2004, single vehicle crashes resulted in over 56% of all fatal crashes recorded on the nation's roadways. Of these fatal crashes, over 14,000 occurred either off of the roadway or on the shoulder. The National Highway Traffic Safety Administration (NHTSA) has recognized that technologies such as electronic stability control and other emerging safety technologies can potentially reduce a great number of these fatal crashes.
One emerging technology that NHTSA believes may have great potential to save lives is lane departure warning (LDW). LDW systems assist the driver by warning them (passive or active) that they are about to depart the road lane. Preliminary NHTSA estimates report that there is a target population of over 12,000 fatalities per year for this technology. The actual number of lives saved will depend upon the effectiveness of LDW systems but could be over 1000 fatalities per year.
This paper will discuss both the past and present LDW research that has been conducted by NHTSA. It will give a general overview of the performance and potential safety benefits from LDW technology. Information on the type of sensors and user interfaces that LDW systems utilize will be presented

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including examples of them. Data from past NHTSA field operational tests and test track research documenting LDW performance will be shown.

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Technical Session: Biomechanics Tools Development

Oral Presentations | Tuesday, June 19, 2007 | 2:00p.m.-5:30p.m.

Chairperson: Jac Wismans, The Netherlands | Track C | Room: Salon Pasteur
Co-Chairperson: Craig Newland, Australia

Paper No. 07-0286-O
Evaluation Of Biofidelity & Repeatability And The Influence Of Different Positioning For THOR-NT Dummy
Masayuki Yaguchi, Koshiro Ono, *Japan Automobile Research Institute*
Mitsutoshi Masuda, *Japan Automobile Manufacturers Association, Japan*

Abstract:
Component tests on the head, neck, thorax, abdomen and face were conducted to evaluate the biofidelity of THOR-NT. HYGE sled tests were also conducted to evaluate repeatability and to investigate the influence of different positioning to dummy responses. Biofidelity evaluation tests were conducted in accordance with test procedures for THOR determined by NHTSA/GESAC, and responses were compared with PMHS response corridors.

Three frontal HYGE sled tests were conducted under the same conditions with a velocity of 56km/h, acceleration of 270m/s2, and a designed standard seat position. Repeatability of dummy responses was evaluated by coefficient of variation (CV) calculated based on the peak values of accelerations, deflections, forces and moments measured. The following three categories were defined as evaluation criteria of repeatability by CV: CV<=5% as good, CV<=10% as acceptable and CV>10% as poor. Furthermore, in order to investigate the influence of different positioning to dummy responses, a 56km/h frontal HYGE sled test was conducted on a dummy positioned according to the ATD positioning procedure developed by UMTRI. In the biofidelity evaluation, only head responses were within the PMHS response corridors. For repeatability, 10 (32%) out of 31 items in all of the data had an evaluation criteria within CV<=5%.

Comparison of dummy responses between UMTRI and standard positioning showed similarity in kinematic responses of the upper body. However, the maximum displacement of ankle in X-direction with respect to the initial position was larger in the UMTRI position compared to the standard position. In the UMTRI positioning, the feet which are initially positioned away from the toe board comes in contact with the toe board and slide upward due to the forward movement to the vehicle body during impact. Due to this, difference in dynamic responses of the legs between the UMTRI and standard position was observed.

Paper No. 07-0293-O
OOP Airbag Tests Using The THOR-NT And Hybrid-III Dummies
Zi Lu, Philemon Chan, *Titan/L-3 Communications*
Stephen Ridella, Peter Martin, *National Highway Traffic Safety Administration, United States*

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Abstract:
An experimental study of driver side airbag loads was performed using the 50th percentile THOR-NT and Hybrid-III dummies seated out-of-position (OOP). The main objective was to evaluate the differences between the two dummy responses to a range of airbag deployments. Each dummy was placed at the ISO-1 position with two tests repeated for each airbag. A total of 25 late-model fleet airbag modules were used. Sealed tank tests were first performed to characterize the inflators. For the accordion-type airbags, both dummies recorded repeatable data with comparable accelerations. Both dummies also recorded comparable head/neck shear and tension loads, but THOR-NT recorded much lower head/neck moments than Hybrid-III, with the occipital condyle (OC) moment even smaller than the cross-sectional moment. For the airbags with random twist or tucked-in folding, both dummies recorded some data variability for the repeat tests, and the high-speed videos confirmed the inflation variability of those airbags. Again, although the overall accelerations were fairly comparable between the two dummies for each airbag model tested, significant differences between the head/neck load trends were observed. Compared to THOR-NT, the Hybrid-III neck recorded a much higher extensional moment and remained mostly in extension. In contrast, the THOR-NT neck remained in flexion considerably longer. The THOR-NT was able to distinguish the smaller moment at the OC joint from the total head/neck cross-sectional moment. The THOR-NT chest and abdomen deformations measured by the CRUX and DGSP instrumentation were reasonable, smooth, and fairly repeatable. A limitation is recognized that only two airbags for each model were used for repeat tests. The paper provides new data using late-model fleet airbags.

Paper No. 07-0294-O

Biomechanical Response Of Head/ Neck/ Torso And Cervical Vertebral Motion To Lateral Impact Loading On The Shoulders Of Volunteers

Koshiro Ono, Susumu Ejima, *Japan Automobile Research Institute*
Koji Kaneoka, Makoto Fukushima, *Department of Orthopaedic Surgery, University of Tsukuba*
Sadayuki Ujihashi, Shintaro Yamada, *Tokyo Institute of Technology, Japan*

Abstract:
To understand the response of the head, neck and torso during a lateral collision, and to investigate the relation between cervical vertebral motion and the occurrence of neck injuries, lateral impact experiments were conducted on the shoulder areas of human volunteers. Test subjects consisted of 8 volunteers (5 males and 3 females). For the analysis of cervical vertebral motions of each subject, a cineradiography system was used. A VICON motion photographic device was also used for the three-dimensional analysis of head/neck/torso motions. In the experiments, 4 levels of impact force (300N C400N C500N, and 600N) were applied considering both the presence and absence of muscle tension.
Cervical vertebral rotations all started at 75 ms, but the time required to reach the peak rotation increased toward the upper vertebrae, with C7 and T1 peaking at 120 ms and the final peak in the head at 170 ms. At around 75-125 ms, the rotation angle of C5 surpassed those of the head and C4 showing that the cervical spine was bending into an S-curve. This phenomenon shows the same type of cervical vertebral motions causing whiplash during a rear-end collisions. Also, extreme compression was at work in the

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vertebral disc and/or the facet joint in C6/C7 and C7/T1, suggesting a high probability of injury occurring in the neck.

Paper No. 07-0296-O

Modelling The Seat Belt To Shoulder-Complex Interaction In Far-Side Crashes

Clay A. Douglas, Brian N. Fildes, *Monash University Accident Research Centre*
Tom J. Gibson, *Human Impact Engineering, Australia*
Ola Boström, Autoliv Research *Sweden*
Frank A. Pintar, *Medical College of Wisconsin and VA Medical Center, United States*

Abstract:
Regulations and interventions to protect far-side occupants in crashes do not currently exist, despite these occupants accounting for 43% of the AIS3+ injured persons and 30% of the overall Harm in side impact crashes. Furthermore, no suitable ATDs or mathematical models have been developed to investigate far-side occupant dynamics. The aim of this study was to investigate seat belt to shoulder-complex interaction during the first phase of a far side impact for incorporation into a multibody occupant model.

The model adaptations were derived based on quasi-static belt slip tests using volunteers and a Hybrid III ATD. The model development was validated for this first phase of impact by comparison with shoulder-belt force-time histories and T1 excursions from a series of lateral far-side sled tests using a variety of human surrogates: PMHS, WorldSID and ThorNT ATDs.

The newly adapted model correctly predicted seat belt to shoulder-complex interaction in 90% of the quasi-static belt slip tests, compared to less than 20% for the Hybrid III ATD. Furthermore, the model was able to predict the increasing level of occupant retention provided by the seat belt when the d-ring moved rearward and pretension increased. For the validation tests, the magnitude and phasing of the shoulder-belt force-time histories were generally within 10% of the PMHS results. In addition, the model was capable of predicting the location of seat belt to shoulder-complex interaction observed in the PMHS tests.

Paper No. 07-0311-O

WorldSID Small Female Side Impact Dummy Specifications And Prototype Evaluation

Bernard Been, *First Technology Safety Systems Europe*
Francois Bermond*, Institue National de Recherche sur les Transports et leur Securite INRETS, France*
Klaus Bortenschlager, *Partnership for Dummy Technology and Biomechanics PDB, Germany*
David Hynd, *Transport Research Laboratory Ltd., United Kingdom*
Luis Martinez, Gustavo Ferichola, *Universidad Polytecnica de Madrid, Spain*
Riske Meijer, *Organisation for Applied Scientific Research TNO, The Netherlands*

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Abstract:
The WorldSID programme was set up to develop a new, worldwide acceptable, advanced technology, side impact crash test dummy for improved assessment of injury risk to car occupants in lateral collisions. Following the release of the mid-sized male WorldSID, the development of the small female WorldSID dummy was initiated by the EC 6th Framework collaborative research project 'APROSYS' in 2004.
The main specifications and requirements of the new dummy have been defined in terms of anthropometry, biomechanical response and instrumentation capabilities in general and per body segment. An overview of the specification is given in this paper. Two prototype dummies have been manufactured according to the requirements and evaluated against a first set of test conditions. Test results include responses from dynamic component and full body tests are presented here, including pendulum impactor, linearly guided impactor and sled tests. For a prioritised matrix of biomechanical test conditions, the dummy responses were compared against the biomechanical human response requirements. Furthermore, the dummy repeatability in well-controlled test conditions was studied and its compliance to anthropometric requirements is reported.
Following the assessment of the dummy's current biofidelity and maturity, recommendations for further dummy improvements are given in the conclusions.

Paper No. 07-0314-O

Scalability Of Human Models

Carmen Rodarius, Lex van Rooij, Ronald de Lange, *TNO Science and Industry, The Netherlands*

Abstract:
The objective of this work was to create a scalable human occupant model that allows the user to adapt human models towards their needs accounting for variable size, weight and several mechanical parameters. In accident analysis for example, such a model is desired to set up simulations with a model representing the actual occupant and not only a standardized one, e.g. the 50th percentile male. Therefore, for the first time two scalable facet human models were developed in MADYMO. First, a scalable human male was created from an existing 50th percentile human occupant. Since the anthropometry of males and females differ too severely, a scalable human female is created as well to obtain adult and teenage female models.

A target model anthropometry can be created either by defining an anthropometry set of 35 values, by defining 16 fixed scale factors or by using the GEBOD database. Additional to the geometric properties, the following mechanical properties are also scaled towards the target anthropometry; mass, inertia, stiffness and contact characteristics. Several anthropometrically extreme models, ranging from small children to large adults, have been created using the 3 possible methods. The definition of the anthropometry values and the fixed scaling factors produced reasonably scaled models, whereas the GEBOD database generated unreasonable models, especially when scaling towards children.

The main limitation of the models is that no age based material dependency is taken into account during the scaling. As a result, the response of the child models is not completely biofidelic. Furthermore, the impact behavior of all models (injuries, range of motion, etc.) is not yet validated. Future work is planned

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to perform accident reconstruction analyses using a normal 50th percentile male and a scaled model to assess the benefit of this work.

Paper No. 07-0338-O

Characterizing Diffuse Brain Injuries From Real-World Motor Vehicle Impacts

Narayan Yoganandan, Thomas A. Gennarelli, Frank A. Pintar, *Department of Neurosurgery Medical College of Wisconsin, United States*

Abstract:

The objective of the study was to analyze real-world cases with a focus on diffuse axonal injury (DAI). Cases were extracted from the Crash Injury Research Engineering Network database (CIREN), developed by NHTSA. Methods involved evaluations of CIREN engineering and medical data including CT/MRI and X-ray images and pre-hospital and Trauma Center records, and impact characteristics including delta-V, principal direction of force, and occupant kinematics. Case-by-case analyses were grouped into factors such as impact mode and injury severity. Out of the 2,815 cases, 43 cases of DAI were identified with 11 fatalities and 32 survivors. Change in velocities ranged from 4 to 24 m/s. Fifteen impacts were frontal (11 to 1 o'clock), and 9 impacts each were considered lateral (2 to 4 or 8 to 10 o'clock). Thirty two of the 43 (75%) DAI cases were associated with head contact; seven cases (16%) where no contact was identified, two cases (5%) where only airbag contact with the head was identified, and remaining were unknown. Twenty three were drivers and no cases involved pregnant occupants. DAI associated with head contact found in significant majority of cases imply the role for the direct impact load transmission as a trauma mechanism. Although DAI were reported in medical records, careful review failed to confirm the injury in all instances based on its classic definition. This will be expounded in the presentation. In this limited database, airbags were not attributed to be the injury causal agent in a significant majority of cases (>90%), implying its minimal role in severe head trauma. Mechanism of diffuse brain injuries, specifically DAI, should not be based solely on radiology reports and diagnostic images. Pre-hospital, hospital, and clinical information should be given due consideration in conjunction with diagnostic images for proper injury assessment. Comparing with data from other sources, present preliminary findings suggest a possible decreasing trend for the occurrence of DAI in modern vehicular environments, possibly with the introduction of newer technologies and restraint use.

Paper No. 07-0354-O

Biomechanical Analysis Of Hard Tissue Responses And Injuries With Finite Element Full Human Body Model

Jay Zhao, Gopal Narwani, *Takata Corporation, United States*

Abstract:

This paper summarizes the development activities on the finite element full human body model, improving upon last 19th ESV publication (ESV 05-0399). The updated Takata human model for an average adult male has anatomical details of skeleton and major soft tissues in all the body parts from head, neck, shoulder, thorax, abdomen, pelvis, lower extremity and upper extremity. The arteries and veins as well as sciatic nerves in pelvis, thigh and tibia regions were also modeled. The model's responses of all the body

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parts were validated against thirty-eight sets of published PMHS test data for both the frontal and side impacts under various pendulum or sled tests conditions.
The model development and validations focused on our needs for restraint related local responses and injuries at tissue level, especially for estimation of hard tissue injuries. Biomechanical analysis has been made on fractures of clavicle, hip joint, knee, femur and tibia using this model. The bone fractures were assessed by both, the localized stress-strain characteristics as well as the global force-deflection responses.
As an example, a detailed analysis for the clavicle fractures study is presented. It was found that the Maximum Von-Mises Stress (MVMS) of the clavicle cortical bone is a good predictor for clavicle fracture. Under side impacts the estimation of clavicle fracture based on the criterion that the MVMS exceeds 120 MPa was in agreement with the criterion based on the global acromion-to-sternum deflection of 47mm currently developed for human clavicle fracture /shoulder AIS 2+ injury. Furthermore, analyses have been made to mid-sized male occupant seated in a car environment subject to seatbelt loading to analyze sensitivity of shoulder forces to bone stress.

Paper No. 07-0399-O

A Proposed Side Impact ATD Bio-Fidelity Evaluation Scheme Using Cross-Correlation Approach

Guy Nusholtz, Timothy Hsu, Lynn Byers, *DaimlerChryser Corporation, United States*

Abstract:
In a continuing effort to better simulate human responses in an anthropomorphic test device (ATD), a new ATD bio-fidelity evaluation scheme is being proposed in this paper. ISO/TR9790 has been in existence for some years for evaluating the bio-fidelity of side impact ATDs. In an attempt to improve upon this, NHTSA recently generated a new approach for creating bio-fidelity corridors. This new approach was considerably different from the ISO method, for example, by incorporating the time factor into the evaluation equation and automating the process (Maltese et al. 2002). Although both the ISO and NHTSA methods exhibit a number of strengths, they also have weaknesses, making them problematic. This paper presents research that attempts to build on these two approaches, in order to develop an effective ATD assessment scheme/method; a method which potentially offers added objectivity, and more importantly, is statistically meaningful. This new process is similar to the cumulative variance approach used in NHTSA¡¯s method. However, improvements were explored in several key areas to address the numeric issues identified by HSU in 2005. This new proposed process uses the complete time history without shifting, and data selection is based on energy and momentum conservation. This helps to overcome difficulties due to instrumentation, test, and calibration errors. To develop this new method, a correlation based SID ATD evaluation scheme was used. Validation of the scheme was performed using the post-mortem human subject (PMHS) as a pseudo dummy. Different methods were explored for classifying a dummy's bio-fidelity. A simple formula is being proposed for ranking the bio-fidelity of the dummy, resulting in a score from 0-10, with 10 being the best. The sensitivity of the results to the formula parameters was studied, as well as the practical application of this proposed method for evaluating the bio-fidelity of a side impact dummy. All three methods were compared using NHTSA¡¯s available side impact PMHS and ATD test data. Both the pros and cons of this proposed ATD bio-fidelity evaluation scheme were evaluated and are detailed in this paper.

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Paper No. 07-0506-O

Comparison Of Kinematic And Thoracic Response Of The 5th Percentile Hybrid III At 40, 48 and 56 Km/H Rigid Barrier Tests

Suzanne Tylko, Dominique Charlebois, *Transport Canada*
Alain Bussieres, *PMG Technologies, Canada*

Abstract:
Full-scale crash tests were conducted to investigate the correlation between the 5th percentile Hybrid III dummy kinematics and chest response at three test speeds. A total of 20 comparative full frontal rigid barrier tests were conducted at 40, 48 and 56 km/h with the dummies placed in the front and rear outboard seating positions. Additional sled tests were carried out to characterize the kinematics of the dummy and the distortion of the jacket observed in 56 km/h barrier tests.
As test speed increases to 56 km/h, the forward excursion and rotation of the thorax increases significantly. This rotation combined with jacket distortions inhibits the accurate measurement of chest deflection. The influence of the seat characteristics, belt geometry at peak load, and the jacket fit, as well as the role of the dummy breasts are explored.
A new multi-point sensing device, known as the RibEye is introduced in full-scale rigid barrier tests and in simulated sled trials to evaluate the role of multi-point sensing in enhancing the accuracy of chest deflection measurements. This new instrumentation may significantly reduce the sensitivity to belt placement associated with traditional single point measurements.
Jacket fit and jacket distortion and rotation about the thorax are difficult parameters to quantify. As a result, the analysis needed to rely on video analysis and comparative measures.

The response of the 5th percentile female, exposed to seatbelt or combined seatbelt/airbag loading conditions at increasing test speeds has never been evaluated. Given that the dummy was designed for blunt impact loading to the thorax it is valuable for vehicle designers and regulators to have a clear understanding of the Hybrid III 5th ATD's capabilities and limitations.

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Oral Presentations | Wednesday, June 20, 2007 | 8:30a.m.-12:00p.m.

Chairperson: Peter Burns, Canada | Track A |
Room: Salle Rhône 3
Co-Chairperson: Kaneo Hiramatsu, Japan

Paper No. 07-0016-O
CICAS-V Research On Comprehensive Costs Of Intersection Crashes
Louis Lombardo (retired), Lawrence Blincoe, Rajesh Subramanian, *National Highway Traffic Safety Administration*
Dan Cohen, James Chang, *Mitretek, United States*

Abstract:
This paper addresses the question: What are the economic and non-economic consequences associated with crashes at intersections in the U.S.? The paper estimates the magnitude of the safety problem that may be mitigated by reducing violations of traffic signals and stop signs using communication technologies to convey information between the infrastructure and vehicles under the U.S. Department of Transportation's Cooperative Intersection Collision Avoidance Systems (CICAS - V) program.

Paper No. 07-0292-O
Evaluation Of The Performance Of Available Backover Prevention Technologies For Light Vehicles
Elizabeth Mazzae, W. Riley Garrott, *National Highway Traffic Safety Administration, United States*

Abstract:
Research Question: How well do current, commercially-available backing aid technologies perform in detecting objects, particularly small children?

Methods: Eight sensor-based systems (two including rearview video), one rearview camera system, and two mirror systems were examined.
The object detection performance of sensor-based systems was measured including static field of view (FOV), detection repeatability, response time, and dynamic detection range for a variety of test objects including an adult male and 1-year-old and 3-year-old children. Assessment of FOV and display image quality was conducted for rear video and auxiliary mirror systems.

Data Sources: Controlled testing was conducted.
Results: Sensor-based systems generally observed ability to detect children was inconsistent and limited in range. Based on calculations of the distance required to stop from a particular vehicle speed, detection ranges exhibited by the systems were not sufficient to prevent collisions.

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Rearview video systems examined displayed obstacles and provided a clear image of the area behind the vehicle in daylight and indoor lighted conditions. While the auxiliary mirror systems tested also displayed rear obstacles, their FOVs covered a smaller area and the displayed images were subject to distortion caused by mirror convexity and other factors (e.g., window tinting) making rear obstacles more difficult for the driver to recognize.

Conclusions: Results showed that the performance of ultrasonic and radar parking aid and aftermarket backing systems in detecting child pedestrians behind the vehicle was typically poor, inconsistent, and limited in range. Detection ranges observed were unlikely to be sufficient to prevent crashes. While sensor-based systems tested showed some deficiencies, it may be possible to improve system performance and detection range. Visual systems display to the driver what is behind the vehicle, but are passive and require driver attention to perceive any obstacles.

Discussion: To fully estimate benefits obtainable from backover avoidance system implementation, it is necessary to know how effectively drivers will use the systems and their rate of compliance with system warnings.

Limitation of Study: It is not known whether drivers will interact effectively with backing aids such that crashes will be reduced.

What does the paper offer that is new in the field?: Describes the performance of current parking aid and backing systems.

Paper No. 07-0149-O

Effects On Driving Performance Of Long-Term Exposure To A Seatbelt Reminder System: Findings From The Australian TAC Safecar Project

Michael Regan, Kristie Young, Thomas Triggs, Nebojsa Tomasevic, Eve Mitsopoulos, Karen Stephan, *Monash University, Australia*

Abstract:

The TAC SafeCar study evaluated the impact of three Intelligent Transport System technologies, alone and in combination, on driver performance: Intelligent Speed Adaptation, Following Distance Warning and a Seatbelt Reminder system for all seated occupants. The project had several aims: to evaluate the technical operation of these technologies; to assess the acceptability to drivers of them; and to evaluate, in an on-road setting, the impact of them, alone and in combination, on driver performance and safety. Twenty-three fleet car drivers (15 treatment and 8 control drivers) participated in the on-road study. Each participant drove a SafeCar for at least 16,500 kilometres. The SafeCar project was the first to evaluate the effects on driving performance of long-term exposure to a Seatbelt Reminder system. The results, reported in this paper, revealed that driver and passenger interaction with the Seatbelt Reminder system led to large and significant decreases in the percentage of trips where occupants were unbelted, in the percentage of total driving time spent unbelted, and in the time taken to fasten a seatbelt in response to

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the seatbelt warnings. The Seatbelt Reminder system was rated by drivers as being useful, effective and socially acceptable, and use of it led to a decrease in drivers' subjectively reported mental workload. Based on the results of the study, use of the Seatbelt Reminder system is estimated to save the Australian community approximately AUD $335 million per annum in reduced HARM costs. These findings were yielded even though initial seatbelt wearing compliance rates were high, suggesting that Seatbelt Reminder systems can be effective in improving seatbelt compliance among occupants who already have high wearing rates.

Paper No. 07-0221-O

ADAS Design Method Based On Real World Driving

Delphine Dubart, Mohamed Kassaagi, , Michèle Moessinger, *Laboratoire d'accidentologie, de biomécanique et d'études du comportement humain*
Maëlle Lefort, *GIST, France*

Abstract:
Recent cars are more and more equipped with advanced driver assistance systems (ADAS). The design of useful and safe ADAS requires real driving behavior data in particular for their specification and their tune-up. Our study is focused on the improvement of adaptive cruise control (ACC) design. The specification of such a system requires drivers' profiles using driver's actions and vehicle dynamic data (speed, acceleration…) as well as information about close traffic in longitudinal regulation situations. An experiment on real road is currently carried out with 120 common subjects driving an instrumented car. To ensure that representative road situations are taken into account, data are recorded in ecological conditions, with common drivers driving a non-ACC equipped car on a 250 km real road. Four data types are recorded: drivers' actions and comments, car dynamic and road environment characteristics. Only results based on objective data will be presented in this paper, for example headways or speed choices in some relevant driving situations and their correlation with drivers' profiles. This experimental method has the advantage to allow understanding both the driver's real need (and not what the technology enables) and his/her real dynamic use of the car. As for any experimental procedure, it is essential to be aware of some biases which could impact the study conclusions. The data collected from this study and also from other ones should enable building an "intelligent" driving algorithm able to classify any driver in a pre-defined category of profile in order to configure automatically the best ACC functioning mode.

Paper No. 07-0254-O

Real World Application Of An Aftermarket Driver Human Factors Real Time Auditory Monitoring And Feedback Device: An Emergency Service Perspective

Nadine Levick, *Objective Safety LLC*
Larry Wiersch, Michael E Nagel, *Cetronia Ambulance, United States*

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Abstract:
Ambulance transport has been demonstrated to be hazardous, however there is limited research on the effectiveness of technologies to minimize these risks. This study evaluates the effectiveness and human factors impact of an aftermarket ambulance driver monitoring device with real time auditory feedback.

The device was evaluated in an urban/suburban EMS group (>80 drivers and 16 medical transport vehicles). Data were collected via an aftermarket onboard computer system monitoring vehicle parameters every second. Penalty counts were recorded for exceeding set parameters with real time auditory feedback to the driver of both warning and penalty tones. Data are downloaded wirelessly daily for analysis. Data collected over a 24 month period included: System miles travelled, miles between incident. Driver specific behaviour and miles between incidents, by age and gender and total miles travelled. Response times and vehicle maintenance were tracked. Incidents that occurred appraised for cost and injuries sustained.

Over 1.4 million miles of vehicle operations were recorded. System wide performance improved in excess of two orders of magnitude over the study period. There was a 20% cost saving in vehicle maintenance within 6 months. There was no increase in response times. There was sustained improvement in safety proxies over 18 months, with no inservice or retraining after the initial introduction period.
A gradual implementation, with rigorous attention to defray any potential concerns of any punitive approach was key.
This real world evaluation of an after market electronic system wide safety technology demonstrated a marked improvement in ambulance transport safety and safety proxies in every measured area. These technologies should be encouraged for widespread implementation throughout the EMS system to optimize safety in addition to cost benefit.

Paper No. 07-0042-O

Performance Of Drivers In Two Age Ranges Using Lane Change Collision Avoidance Systems In The National Advanced Driving Simulator

Alrik Svenson, *National Highway Traffic Safety Administration*
Valerie Gawron, *General Dynamics*
Timothy Brown, *National Advanced Driving Simulator, United States*

Abstract:
Lane change collision avoidance systems (CAS) are designed to prevent crashes in lane change maneuvers by alerting the driver to hazards in the adjacent lanes of traffic. These systems detect surrounding vehicles that are on the sides and behind the vehicle, notify the driver through warning signals, e.g., a visual symbol in the side or rear view mirrors, and have the potential to reduce the fatalities and injuries associated with these collisions. Currently, these systems are being introduced into new vehicles; however test data of driver performance using them remain limited.
The objective of this research is to examine driver behavior using lane change CAS to determine what leads to the safest driver behavior, and to investigate if the use of a lane change CAS with only a

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proximity warning system (i.e., blind spot detector) provides sufficient warning to drivers. This study considers drivers in two age ranges with comparatively high crash statistics in these types of crashes: 16-21 years of age, and 65 and older. Simulator test scenarios developed for the National Advanced Driving Simulator (NADS) at the University of Iowa are used to examine and compare five lane change CAS types, a representative commercially-available proximity warning system, TRW proximity-only CAS system, TRW comprehensive system, a left (driver's) side convex mirror, and a baseline (standard vehicle mirrors). At the 19th ESV Conference, Svenson et al. (2005) presented the methods for evaluation of several lane change CAS using the NADS. That paper gave preliminary results on the younger driver's acceptance of the lane change CAS and decision to use CAS information in making lane change decisions. This paper contains the complete data set (32 drivers) and final test results for both age ranges. A discussion of results that includes a comparison of the experiences of both age ranges and conclusions of the study are presented.

Paper No. 07-0383-O

The Influence Of Study Design On Results In HMI Testing For Active Safety

Bruce Artz, Mike Blommer, Reates Curry, Jeff Greenberg, Dev Kochhar, Louis Tijerina
Ford Motor Company, Sweden
Martin Fagerstrom, Lotta Jakobsson, Mikael Ljung, *Volvo Cars, United States*

Abstract:
Active safety systems show great potential in preventing a large number of accidents. However, unless the system is completely autonomous, its actual effect will depend on how well it interacts with the driver. Therefore, HMI testing for active safety systems has become central in their development. For reasons of reproducibility and safety, HMI testing is usually carried out in a driving simulator or test track environment. These environments are different from real life driving. Therefore, unless the study design accurately reflects the conditions under which the system will be used, results will have low validity. Hence, study design becomes very important.

The influence of study design was clearly shown in three studies of a Forward Collision Warning (FCW) system carried out by Volvo Cars and Ford Motor Company in VIRTTEX, Ford's motion-based driving simulator. In each study 48 subjects were exposed to a surprise FCW event, with 36 subjects getting a warning from the FCW system. Results show that drivers' reactions to the warning largely depended on their degree of previous exposure to warning systems as well as the type of warning. Drivers who had practiced driving and interacting with other active safety systems prior to the surprise FCW event responded as intended to all warning types. Drivers who were neither trained with nor informed about active safety systems prior to the surprise event did not respond as intended to the warnings, with an interesting exception for verbal warnings.

These results show to achieve high validity in HMI evaluations, the study design must expose drivers to systems in a way that reflects their normal system awareness in real life driving. It also means that active

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system developers should optimize HMI designs towards frequency of use, as well as keeping drivers adequately aware of available systems.

Paper No. 07-0082-O

Developing Guidelines For Managing Driver Workload And Distraction Associated With Telematic Devices

Donald Bischoff, *National Highway Traffic Safety Administration (retired); Private Consultant, United States*

Abstract:

The explosive growth of in-vehicle telematic devices has brought with it a safety concern since there is the potential for distraction of the driver away from the driving task. To address this concern the Alliance of Automobile Manufacturers formed a work group of experts from the auto industry, government and other stakeholders (ITSA, SAE, CEA, AAA, NSC, TMA and others) and tasked them with developing a "best practices" document to address essential safety aspects of driver interactions with future information and communication systems. This effort, which has been ongoing for 6 years, has produced 3 iterations of the document "Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems." These Guidelines address the design, use and installation of information and communication systems with the goal of minimizing driver distraction associated with their use. The publication of the Guidelines has been followed by a letter of commitment from the Alliance members to design all their production vehicles to these Guidelines within specific designated timeframes.

The Working Group has made a commitment to harness and apply state-of-the-art scientific understanding to the continuing evolution of its Driver Focus Guidelines. In that effort the group has benefited from work in Europe, Japan and the U.S. sponsored by both the private and public sectors. The purpose of this paper is to explore the extensive ongoing relevant research in the area of driver distraction and workload management and show how it has been utilized in the latest iteration of the Guidelines. The intent is that the Guidelines can be utilized to design telematic systems that stretch the envelope for systems that enhance the safety of drivers consistent with the state-of-the-art knowledge with regard to minimizing the potential for driver distraction.

Paper No. 07-0057-O

Evaluation Of Driver Mental Workload Facing New In-Vehicle Information And Communication Technology

Annie Pauzié, *French National Institute for Transport and Safety Research*
Julie Manzano, *INRETS/LESCOT, France*

Abstract:

It is important to evaluate driver's mental workload in the area of in-vehicle design, as the evaluation of the cost of the task is a way to have assessment of the potential safety, usability and acceptability of

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these systems. Nevertheless, it is a difficult variable to assess, in comparison with other criteria such as the driving performance, for instance, where recording of objective data are reliable and easy to conduct. For this purpose, the NASA-TLX has been one of the most often used. Nevertheless, this tool has been set up in the context of airplane pilots, and was not fitting with the reality of the driving task, so INRETS/LESCOT proposed a new tool called DALI for Driving Activity Load Index. This tool has been already used for the evaluation of hand-free phone and guidance system impact on the driving activity.
In order to better understand its advantages and limits, a real road experiment has been conducted with the purpose to compare 4 driving contexts varying by their level of workload for the driver. This research has been conducted in the framework of the European project AIDE (Adaptative Integrated Drive-Vehicle interface), in cooperation with vehicle manufacturers.
Results of the DALI were significantly different according to the level of demand for each experimental session. Furthermore, this method allowed identifying if the origin of the driver's workload was perceptive, such as visual or auditory, or more cognitive such as attentional requirements for each context. This tool is made available for any further research in this area.

Paper No. 07-0262-O

Driving Simulator As An Evaluation Tool – Assessment Of The Influence Of Field Of View And Secondary Tasks On Lane Keeping And Steering Performance

Gwendolin Knappe, Andreas Keinath, Klaus-Josef Bengler, *BMW Group*
Cristina Meinecke, *Friedrich-Alexander Universität Erlangen-Nürnberg, Germany*

Abstract:
The development of new sophisticated in-car systems, fostered by technical innovation, demands careful evaluation of these systems. Driving simulation is an important tool for this kind of evaluation. In-depth knowledge of the driving simulator as a tool as well as of metrics recorded and calculated while using the simulator is needed to improve new driver information systems or similar devices during the development process.
For this reason four experiments, with numbers of participants varying between 16 and 30, were conducted to investigate the sensitivity of lane keeping and steering metrics. Participants were exposed to varying fields of view as well as cognitive and visual-motor secondary tasks.
The results yielded by the first three experiments were quite consistent. For the fourth experiment similar results are expected.
All metrics are more sensitive to visual-motor secondary tasks and the reduction of the peripheral field of view than to cognitive secondary tasks. Out of the various steering metrics the "steering wheel reversal rate" showed the best results. "Time to line crossing" and the "standard deviation of lane position" were the most sensitive of the lane keeping metrics. Since the difficulty in implementing and analyzing the examined metrics differs vastly these results can help in choosing suitable metrics in an economic manner. It turned out that harmonization is needed with regard to the various calculation methods of some of the metrics.

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Another topic was subjects' level of experience to take part in a driving simulator study. We found out that just a short period of training was necessary to be perfectly prepared for this kind of experiment. Interpretation of the results is limited to the age group of 20 to 36 years old male persons.

Paper No. 07-0272-O

Driver Strategies When Interacting With Information And Entertainment Systems

Laurence Rognin, *LAB PSA Peugeot Citroen Renault*
Antoine Lescaut, *PSA Peugeot Citroen*
Sophie Alidra, *INTA*
Clément Val, *Centre européen d'études de sécurité et d'analyse des risques*
Xavier Chalandon, *Renault, France*

Abstract:
Whereas more and more information and entertainment systems are developed and introduced in cars, their impact on driving safety and more specifically on driver loss of attention is questioned. Several methods aiming to measure the driver distraction induced by such systems are currently discussed at an international level (ISO WG8, SC13). One of these methods, denoted the Lane Change Test (LCT) aims to measure quantitatively the degradation of the driving performance induced by secondary tasks. Following previous work conducted by various entities, the present study investigates the robustness of LCT at two levels. The first objective is to assess the relevance of the method to discriminate among different design options. The second objective is to assess the impact of the experimental set-up on the robustness of the method. To achieve these objectives, an experiment involving 18 subjects is conducted in a PC environment and in a vehicle-based simulator, from September to November 2006. A calibration task, derived from the ADAM project is used to compare performance in PC and in simulator environments. In vehicle-based simulator, three similar secondary tasks are performed in four different vehicles: the change of radio frequency, the selection of a radio station in a list and the entry of data in a navigation system. In addition to the main indicator suggested in the LCT procedure (mean lateral deviation), three categories of indicators are calculated: driving task (trajectory, distance covered, speed, position on lane), lane change (latency, duration, range, quality) and secondary tasks (latency, duration, quality and complexity). Results from the on-going experiment will be detailed in the final paper, where driver strategies when interacting with in-vehicles displays will be described and associated degradation due to driver distraction highlighted. To conclude, limitations of the method will be discussed. Typically, the low realism of the monitoring tasks (limited to detecting front view information), learning effect and its impact on comparison between successive vehicles will be covered and the added value of this method compared to traditional heuristic evaluations and user testing will be debated.

Paper No. 07-0473-O

Evaluating The Comprehensibility Of Visualized Information For The Trans European Road Network (TERN) As Part Of The EU Project IN-SAFETY: Infrastructure And SAFETY

Technical Session: Advanced Technology Human Performance

Karin Siebenhandl, Hanna Risku, Christof Brugger, *Danube University Krems, Department of Knowledge and Information Management*
Peter Simlinger, Stefan Egger, *IIID, Austria*

Abstract:
The IN-SAFETY Project is focussing on the pre-requisites for a successful implementation of Intelligent Transport Systems (ITS) in order to enhance the self-explanatory nature of roads.
The European driver has to cope with more and more complex traffic environments, including vertical and horizontal signing; many of them are supported by telematics. Thus, there is a high need for a self-explanatory road environment at a personalized level, which would offer intuitive guidance to the driver and information when this is needed. This information should be related to the driver's particular needs (route, disabilities, preferences, etc). A self-explanatory road will protect the driver from making errors and will enhance his/her comfort.

Due to the complexity of information on the road there is strong need to support the driver with homogenized pictorial messages along his way on the Trans European Road Network.
Information contemporary displayed on Variable Message Signs (VMS) is usually shown in the local language. The readability and understand ability of VMS (Variable Message Sign) messages will be addressed in this presentation:
A pictogram to be included into the final proposal to the EC is to pass several stages of development. Danube University carries out the tests of pictograms for comprehensibility in order to substitute verbal messages as used on roads. The various stages in the development and testing procedure for IN-SAFETY symbols follow the evaluation criteria and methods of ISO 9186 “Test methods for judged comprehensibility and for comprehension“.
The presentation will discuss as well the evaluation as the results of the test series, done in Austria, Hungary, Spain, Czech Republic and the Netherlands.

Technical Session: Advanced Technology Human Performance

Technical Session: Compatibility in Frontal/Side Collisions

Oral Presentations | Wednesday, June 20, 2007 | 8:30a.m.-12:00p.m.

Chairperson: Pierre Castaing, France | Track B |
Room: Amphitheatre Pasteur
Co-Chairperson: Eberhard Faerber, Germany

Paper No. 07-0323-O
Chances For A World Wide Compatibility Evaluation - German Car Manufacturer's Position Paper On Crash Compatibility
Willibald Ablassmeier, *AUDI AG*
Thomas Slaba, Stefan Walner, *BMW AG*
Markus Hartlieb, *DaimlerChrysler*
Steffen Boening, *Fordwerke AG*
Bert Wrobel, *Adam Opel AG*
Martin Kamm, *Dr.Ing.h.c F.Porsche AG*
Sean O'Brien, *Volkswagen AG and RMIT University Melbourne*
Thomas Schwarz, Robert Zobel, *Volkswagen AG*
Hans-Thomas Ebner, *VDA, Germany*

Abstract:
German passenger car manufacturers (VDA) provided a position paper that has the potential to combine research by the American Alliance of Automobile Manufacturers with that of IIHS as well as the efforts of German EEVC to constitute a feasible and realistic step for a worldwide compatibility evaluation. This paper provides the technical background of the concept behind this suggestion and estimates the benefit to be achieved. It discusses the relationship between self and partner protection in the current European accident scene and discusses benefits and draw-backs of alternatives currently being discussed in the various groups involved in compatibility research.
Compatibility offers the opportunity to increase safety in a limited manner, but by reducing self-protection of passenger cars, it has the potential to significantly compromise the currently very positive development of the national safety figures in Europe.

Paper No. 07-0348-O
Vehicle Compatibility Assessment Using Test Data Of Full Frontal Vehicle-to-Vehicle And Vehicle-to-Full Width Deformable Barrier Impacts
Saeed Barbat, Xiaowei Li, Steve Reagan, Priya Prasad, *Ford Motor Company, United States*

Abstract:
This paper provides an update of Ford's research activity in vehicle compatibility. The current challenge for motor vehicle manufacturers is an ability to extrapolate compatibility performance in real-world

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accidents using data from controlled crash test environments. Several test procedures and various compatibility measures which use data obtained from rigid or deformable barrier tests to quantify expected compatibility with smaller vehicles have been previously proposed. The purpose of this research is to examine potential compatibility measures obtained from vehicle-to-barrier impact as well as to evaluate the effectiveness of the "BlockerBeam" in vehicle-to-vehicle impacts. The BlockerBeam is a Secondary Energy Absorbing Structure (SEAS) attached to the front end of the rail/frame of an SUV or full size pick-up below the bumper. It improves structural interaction and reduces override during frontal impact with a passenger car and is expected to provide potential improvement in the injury outcomes of the occupants in the struck passenger car.

The current research presents data analyses obtained from vehicle-to-barrier and vehicle-to-vehicle crash tests to develop assessment methodologies intended to evaluate vehicle compatibility. Full size, heavy duty pick-ups with and without a BlockerBeam were instrumented and tested in a 56 km/h frontal impact against a full width deformable barrier. The barrier consisted of 128 high resolution, 125 mm by 125 mm load cells arranged in a 16 row by 8 column matrix. Identical full size pick-ups with and without a BlockerBeam were also tested in vehicle-to-vehicle full frontal impact. In these tests, the impact speed of the bullet vehicle (full size pick-up) was set to a value intended to induce a 56 km/h velocity change in the stationary target vehicle (small size 4-door sedan). The bullet and target vehicles were equipped with instrumented 50th% dummies in the mid-position for the drivers and 5th% dummies in full forward position for the passengers.

Test data collected from load cells in the barrier tests was reviewed and analyzed to evaluate potential compatibility measures for use in assessing vehicle-to-vehicle crashes. Correlation between barrier test results and vehicle-to-vehicle test results for assessment of compatibility measures and test procedures is discussed.

Paper No. 07-0291-O

Enhanced Vehicle Collision Compatibility In USA- Progress Report Of Technical Workgroup For Front-To-Front Compatibility

Mukul Verma, *EVC Technical Workgroup for Front-to-Front Compatibility, United States*

Abstract:

The Enhanced Vehicle Compatibility (EVC) technical workgroup was created in order to develop solutions for improving crash compatibility between passenger cars and light truck based vehicles (LTVs). Organized initially by the Alliance of Automobile Manufacturers, this workgroup now has members from automakers as well as from the Insurance Institute for Highway Safety, Transport Canada, and the United Kingdom Transport Research Laboratory. Studies conducted by members of this workgroup have led to recommendations for primary and secondary energy absorbing structures for LTVs to improve collision compatibility in frontal crashes with cars. These recommendations include criteria for increased geometric overlap as well as minimum structural strength requirement in the case of secondary structures. They have been voluntarily accepted as performance criteria by almost all manufacturers for LTVs sold in the

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USA. Estimates are presented of the likely benefits resulting from these criteria on the overall safety in vehicle to vehicle crashes.

In addition, the members of the technical workgroup are researching methods to measure and predict the structural interaction of vehicles in crashes and to quantify their relative stiffness. Ongoing work on three parallel paths of research for improving vehicle compatibility is described in this paper - (a) full-width fixed deformable barrier approach; (b) development of mobile deformable barrier as a test device; and (c) CAE-based evaluations of vehicle to vehicle impacts.

Paper No. 07-0105-O

The Study Of The Frontal Compatibility With Consideration Of Interaction And Stiffness

Takeo Mori, Toshiya Kudo, Naoya Kosaka, Harutoshi Motojima, *Toyota Motor Corporation, Japan*

Abstract:

The impact of incompatibility between a large and a light car was estimated in accident analyses. Though self-protection is most important, the compatibility performance of both vehicle types in car-to-car crashes has to be improved. In this paper the concept for improving the compatibility between a small car and a SUV is studied.

In accidents, mismatches between colliding vehicles are found, e.g. in structural geometry, vehicle frontal stiffness and so on. For improving compatibility, these mismatch issues have to be solved in a first step. The concept investigated in this study, discusses three problems. The first one is “Multi load path including mechanical parts”. To ensure a good interaction between colliding vehicles under the existing mismatch of structural parts, it is effective to make use of mechanical parts as a load path, such as an engine with transmission, a wheel (tire) and so on. The second is “To increase the amount of energy absorption (EA) of front body parts”. Increasing the EA amount of these parts is efficient to improve the cabin integrity – as long as the restraint systems can manage an acceptable ride-down of the occupants. The third is “Sufficient stiffness of a passenger compartment”. To crush the front body parts for making the enough amount of EA, the proper stiffness of the passenger compartment is prerequisite.

For improving the compatibility, to satisfy these three items simultaneously is effective. According to the results of crash analyses between a small car and a SUV, the concept for further improving the compatibility is investigated. Then structures applied the concept are studied from the viewpoint of load flow and energy absorption mainly by conducting CAE simulations. The improved structures were tested using actual vehicles for the verification of the concept and the effectiveness of the concept is confirmed.

Paper No. 07-0244-O

Methodological Physical Analysis Of FWDB And PDB Test Procedures Regarding Incompatible Physical Phenomena Observed In Real Life Accident

Donat Coulombier, Richard Zeitouni, Gilles Le Borgne, *PSA Peugeot Citroën, France*

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Abstract:
Many studies have been performed in the field of compatibility between cars. Two test procedures with assessment have been developed to evaluate the compatibility level. The FWDB test is conducted at 56km/h against a 100% overlap rigid wall with deformable elements. The PDB test is a 50% overlap test at 60km/h against a progressive deformable barrier. Assessment criteria are based on the effort for FWDB test and on the deformation of the barrier for the PDB test.
If new assessment criteria are often proposed, few outcomes are provided concerning test procedures themselves, even though a lot of open issues still exist.
The aim of this paper is not to review all of them, but to conduct a methodological and physical analysis of both candidate test procedures. “Physical analysis” because based on the three incompatibility physical phenomenon responsible for real world incompatibility (geometry, energy and stiffness mismatching), and “methodological” because both test procedures are studied by tests and virtual testing. Assessment criteria are therefore not considered.
Moreover, as a general agreement exists today that multiple load path with connections could help car front ends to interact, PSA will present component tests and virtual testing with or without lower load path.
Significant outcomes will be provided concerning the efficiency of the technical procedures:
1) Both procedures can detect a geometry change like the absence of load path.
2) Both procedures can measure a global force. However, its interpretation for the FWDB test is difficult due to the very limited deformation of the front end.
3) Only the PDB test is able to draw up an energy absorption statement which is the only way to evaluate the car crash severity. For the FWDB test, this point represents a major difficulty because energy absorption by deformable elements is significant, about 50kJ.

Paper No. 07-0261-O

Second Report Of Research On Stiffness Matching Between Vehicles For Frontal Impact Compatibility

Shigeru Hirayama, Taisuke Watanabe, Kazuhiro Obayashi, Tomosaburo Okabe, *Nissan Motor Co., LTD., Japan*

Abstract:
The Introduction of various vehicle safety standards and new car assessment programs in addition to automobile manufacturers' efforts to improve vehicle safety performance have led to the significant improvement of vehicle safety performance over the past years. The improvement of impact compatibility is recognized as an approach to further help enhance vehicle safety performance. Through many studies, the fundamental issues of frontal impact
compatibility have become clear. First step is to enhance structural interaction between the front-end structures of vehicles and next step is to help match stiffness between vehicles. Various approaches to improve frontal impact compatibility have been proposed and discussed. In the previous ESV conference, the authors reported the study in which stiffness matching in car-to-SUV frontal impact was tried by adjusting car's stiffness. In this paper, stiffness matching in car-to-SUV frontal impact by adjusting SUV's stiffness was studied. The result obtained from the study will be described. Then, concerns of stiffness

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matching in car-to-SUV frontal impact will be summarized. Finally, approach to resolve the concerns will be proposed.

Paper No. 07-0112-O

Evaluation Of Stiffness Matching Concepts For Vehicle Safety Improvement

Krishnan Subramaniam, Mukul Verma, Ronald Tedesco, Rajesh Nagappala, Louis Carlin, *General Motors, United States*

Abstract:

The concept of 'stiffness mismatch' between front structures of colliding vehicles has been viewed as one of the important factors in collision incompatibility in front-to-front crashes between vehicles of different size. Consequently, it has been hypothesized that 'better matching' of stiffness properties of the front structure of the colliding pair of vehicles may improve the safety of the occupants of the smaller vehicle in such crashes. However, since the front structures of automobiles are designed to meet the protection requirements for their occupants in various frontal impacts, any changes in these properties need to be evaluated for possible influence on all requirements of self-protection as well as of improved compatibility. This paper examines statistical data to estimate the portion of the vehicle front end that may be of significance in front-to-front collision compatibility. The structural properties of an LTV's front structure were modified to reduce the force and energy levels during the front four hundred millimeters of its crush in order to bring its stiffness properties closer to that of a representative midsized car in the US fleet. Detailed studies were conducted for this modified LTV utilizing finite-element based simulations of frontal NCAP test as well as of a frontal impact with a passenger car in a field-representative test configuration. Results of these studies show that changing the structural properties of the LTV to be closer to that of the passenger car may have negative consequences for the protection of the LTV occupants. Alternative scenarios for achieving the proper balance in vehicles' structural properties to improve overall safety are proposed.

Paper No. 07-0180-O

Investigation Of Structural Factors Influencing On Compatibility In Vehicle-To-Vehicle Side Impacts

Satoshi Takizawa, Eisei Higuchi, Tatsuo Iwabe, Masahiko Emura
Honda R&D Co.,Ltd
Takayuki Kisai, Takayuki Suzuki, *PSG Co.,Ltd, Japan*

Abstract:

The aim of this study is to identify how vehicle safety during side impacts may be enhanced by changes to the structures of bullet vehicles. Side impact tests being conducted around the world are focusing on the improvement of self-protection performance of target vehicles, based on existing vehicle fleets. However, the protection of occupants in the target vehicle is influenced both by the characteristics of the target vehicle and the characteristics of the bullet vehicle. Since test procedures for frontal impact compatibility are currently being planned, those that encourage homogeneity and good structural

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interaction among vehicles may also be beneficial for side impacts. Thus, it is necessary to investigate the design factors of the bullet vehicle in terms of side impact compatibility.
First, a study using FE simulation was carried out to develop an understanding of the major influencing factors relating to side impact compatibility. From this understanding, concept ideas for enhancing vehicle side impact compatibility were proposed. Second, vehicle-to-vehicle tests using modified bullet vehicles were performed to demonstrate the principles identified in the FE simulation. Finally, FE simulation of a Full Width Deformable Barrier test was conducted with unmodified and modified vehicles to check that the test and assessment technique could correctly distinguish the improved performance of the modified vehicle.
The results showed that the matching of geometry and stiffness in vehicle front-end structure contributes significantly during side and frontal impacts.

Paper No. 07-0088-O

Current Status Of The Full Width Deformable Barrier Test

Mervyn Edwards, Huw Davies, Richard Cuerden, *TRL Ltd., United Kingdom*

Abstract:
To improve compatibility in car frontal collisions it is generally agreed that better structural interaction, matching frontal forces (stiffnesses) and a strong occupant compartment, in particular for small cars, are required. The Full Width Deformable Barrier (FWDB) test is part of a portfolio of tests being considered to assess and control both compatibility and self protection in car frontal impacts. For compatibility, it aims to assess a vehicle's structural interaction potential using measurements from a high resolution Load Cell Wall behind the deformable element. For self protection, it aims to provide a high compartment deceleration pulse, similar to the current US NCAP test, to assess a vehicle's restraint system.

This paper details the current status of the FWDB test, clarifies remaining issues including test repeatability and describes the new 'Structural Interaction' (SI) criterion. The SI criterion is designed to ensure that vehicles have an adequate structure in a common interaction area to interact with their collision partners and to encourage multi-load path stable structures. It consists of vertical and horizontal components that are divided into parts that could be adopted in a stepwise manner, to allow the gradual development of more compatible vehicles, appropriate for application in a regulatory framework.

This work forms a contribution to the EEVC WG15 co-ordinated research.

Paper No. 07-0331-O

EEVC Approach To Develop Test Procedure(s) For The Improvement Of Crash Compatibility Between Passenger Cars

Eberhard Faerber*, Bundesanstalt fuer Strassenwesen, Federal Highway Research Institute, Germany on behalf of EEVC WG15, Germany*

Technical Session: Compatibility in Frontal/Side Collisions

Abstract:
As set out in the Terms of Reference, the objective of European Enhanced Vehicle-safety Committee (EEVC) Working Group (WG) 15 Car Crash Compatibility and Frontal Impact is to develop a test procedure(s) with associated performance criteria for car frontal impact compatibility. This work should lead to improved car to car frontal compatibility and self protection without decreasing the safety in other impact configuration such as impacts with car sides, trucks, and pedestrians.

In the recent more than three years EEVC WG 15 served as a steering group for the car-to-car activities in the "Improvement of Vehicle Crash Compatibility through the development of Crash Test Procedures" (VC-COMPAT) project finalised end of 2006 and partly funded by the European Commission.

This paper presents the research work carried out in the VC-COMPAT project and the results of its assessment by EEVC WG 15. Further other work presented by the UK and French governments and the industry, in particular the European industry was taken into consideration. It also identifies current issues with candidate test procedures. The candidate test procedures are:
- an offset barrier test with the progressive deformable barrier (PDB) face
- a full width wall test with a deformable aluminium honeycomb face and a high resolution load cell wall as well as using the forces measured in the offset deformable barrier (ODB) test.

These candidate test procedures must allow the assessment of structural interaction and if applicable give information of frontal force levels and compartment strength.

Further, this paper presents the planned route map of EEVC WG 15 for the evaluation of the proposed test procedures and assessment criteria.

Paper No. 07-0303-O

PDB Barrier Face Evaluation By DSCR And NHTSA's Joint Research Program

Pascal Delannoy, Teuchos - *UTAC Passive Safety Department*
Tiphaine Martin, *UTAC, France*
Susan Meyerson, Lori Summers, Christopher Wiacek, *National Highway Traffic Safety Administration, United States*

Abstract:
Vehicle compatibility combines aspects of both self and partner protection. Self protection involves a vehicle's compartment strength and occupant protection systems. Partner protection involves vehicle design attributes that work towards providing occupant crash protection of a vehicle's collision partner. Research has suggested that crush force matching (or good engagement of the front structures) and high compartment strength are essential components for improving compatibility between passenger cars and other vehicles. However, recent trends have shown that incompatible force distributions and greater relative front end stiffnesses are prevalent in the fleet. To research this issue, the Progressive

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Deformable Barrier (PDB) face was evaluated for its ability to assess the compatibility between the front end force of heavier vehicles with the compartment strength of lighter ones.

The paper investigates the feasibility of a high energy absorption PDB face in full frontal and offset frontal crash test configurations. A joint research program was carried out by UTAC and NHTSA to investigate whether barrier deformation using the PDB barrier face could differentiate compatibility performances between two different light trucks.

Paper No. 07-0231-O

NHTSA's Recent Vehicle Crash Test Program On Compatibility In Front-To-Front Impacts

Sanjay Patel, David Smith, Aloke Prasad, *National Highway Traffic Safety Administration, United States*

Abstract:

This paper presents an overview of NHTSA's recent light vehicle compatibility crash testing program. The objective of this testing program is to explore the potential for reducing injuries by improving the crash compatibility between light vehicles. This was done by first identifying the most promising metrics to characterize full frontal crash compatibility using data taken during frontal NCAP testing, selecting crash test vehicles based on the metrics, and finally, performing full-frontal vehicle-to-vehicle crash tests to evaluate the probability of belted occupant injury and fatality in the crash vehicles. The test series provided evidence that by maintaining structural alignment and matching frontal energy absorptions, the probability of injuries/fatalities in both the LTVs and passengers cars can be significantly reduced. This test design process and the results it produced will be presented and discussed.

Carmakers are now voluntarily addressing compatibility using Secondary Energy Absorbing Structures (SEAS) and Advanced Compatibility Engineering (ACE). Vehicle-to-vehicle tests were also conducted to understand how these new concepts perform and what sort of additional characteristic measures and performance tests may be needed. The results of these tests will be presented and discussed.

The advent of SEAS structures also presents challenges to characterize and measure their performance. A new override barrier (ORB) concept has been developed and tested for this purpose. The preliminary design and testing of the ORB will be presented and discussed.

Finite element studies of vehicle-barrier interactions suggest that the 4x9 load cell barriers used prior to 2006 introduced low estimates of force heights on the barrier. In order to better understand the error content in previous estimates of force height, several vehicles were crash tested into a high resolution barrier. The results of this crash test program and their implications will be presented and discussed.

Paper No. 07-0327-O

The Development Of A Mobile Deformable Barrier Test Procedure

Ton Versmissen, Richard Schram, *TNO Science and Industry, The Netherlands*

Technical Session: Compatibility in Frontal/Side Collisions

Abstract:
Frontal compatibility assessment, including self and partner protection, is still a major topic in crash safety testing today. Currently none of the regulatory and consumer test procedures is able to assess the vehicle on vehicle frontal compatibility on the three main aspects; structural interaction, frontal stiffness and compartment strength. It is hypothesized that a test procedure using a Mobile Deformable Barrier (MDB) could be able to assess compatibility on the aspects mentioned above. This paper presents a MDB test trolley for frontal offset testing and its full scale test results.

First, a load sensing trolley was developed. The specifications of the trolley (mass, CoG and inertia properties) are based on EU and US vehicle geometry databases. The trolley mass was made adjustable between 1300 kg and 1700 kg, with tunable inertia properties. The trolley was designed to be equipped with the progressive deformable barrier (PDB) as deformable element. The PDB was chosen based on the available test-data and for its stability and its ability to allow a barrier face deformation measurement to evaluate partner protection.

Based on the current PDB test protocol, a test protocol has been developed for the MDB, called MPDB test procedure. A number of vehicles, ranging from small to large, were tested according the MPDB protocol. The closing speed was selected such that comparable energy as in a static PDB test was involved for a mid sized car. The test results with the full scale MPDB tests were analyzed and compared to test results of static PDB tests. It was concluded that for small vehicles the severity of the MPDB tests is relatively higher than for larger vehicles. The MPDB test procedure was shown to be feasible and repeatable. Further investigations into test parameters are recommended.

Paper No. 07-0195-O
Full-Width Tests To Evaluate Structural Interaction
Yuji Arai, Kunio Yamazaki, *Japan Automobile Research Institute*
Koji Mizuno, *Nagoya University*
Hidenobu Kubota, *Ministry of Land, Infrastructure and Transport, Japan*

Abstract:
For structural interactions in frontal car-to-car crashes, the longitudinal member ground height matching and the homogeneity of structures are significant for compatibility, and barrier force distributions in full-width tests have been proposed to assess these key factors. In this study, full-width rigid and deformable barrier tests at 55km/h were carried out to examine some compatibility metrics such as average height of force (AHOF) and force distribution. The results demonstrated that the deformable barrier will be useful to examine the multiple load paths and shear connections between members, whereas if only to assess the longitudinal member front-end height, the rigid barrier will be more useful.

Paper No. 07-0056-O
Bumper Bag For SUV To Passenger Vehicle Compatibility And Pedestrian Protection

Technical Session: Compatibility in Frontal/Side Collisions

Bengt Pipkorn, Rikard Fredriksson, Jan Olsson, *Autoliv Research, Sweden*

Abstract:
An external airbag for improved sport utility vehicle (SUV) to passenger vehicle compatibility was developed. The performance of the airbag was evaluated by means of mechanical crash tests and mathematical simulations. SUV to passenger vehicle side impact crash tests were carried out. In the tests a Ford Explorer with and without external airbag was impacting a Toyota Corolla. The impact angle was 90 degrees and the impact velocity was 48 km/h (30 mph). It was found that the external airbag reduced the peak intrusion velocities and distances of the b-pillar significantly.

The intrusion velocities and distances were used in sled tests to obtain the potential reductions in occupant injury measures. In the sled tests a state of the art occupant protection system was used that comprised a side airbag and an inflatable curtain. It was found that head, chest and pelvis injury measures were significantly reduced when a bumper bag was used in a SUV to passenger vehicle side impact.

A pedestrian evaluation was also carried out with the external airbag using the same bag as in the SUV to passenger vehicle side impact test carried out. Both impact and out of position tests were carried out. In the impact test a pedestrian legform was impacting the front of the Ford Explorer without and with external airbag. It was found that the bumper bag reduced bending angle, shear displacement and tibia acceleration significantly. In the out of position tests the values were also significantly below the injury assessment values for the lower extremity.

The external airbag was mounted below the bumper structure of the Ford Explorer. The volume of the bag was 134 liters. The peak pressure of the bag when loaded was 7 bars. Future development of the external airbag system will include improved frontal impact compatibility.

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Technical Session: Rear Impact Injury Prevention

Oral Presentations | Wednesday, June 20, 2007 | 8:30a.m.-12:00p.m.

Chairperson: Anders Lie, Sweden | Track C |
Room: Salon Pasteur
Co-Chairperson: Lex van Rooij, The Netherlands

Paper No. 07-0160-O
Influence Of Vehicle Properties And Human Attributes On Neck Injuries In Rear-End Collisions
Yoichi Watanabe, Satoko Ito*, Institute for Traffic Accident Research and Data Analysis (ITARDA), Japan*

Abstract:
Focusing on neck injuries of so-called whiplash in rear-end collisions in Japan, the relationship between human attributes and the number of treatment days of the injuries is analyzed in order to clarify the influence of human attributes on the injury severity.

Based on the integrated accident database developed by the Institute for Traffic Accident Research and Data Analysis (ITARDA), the regression analysis using ordered response model in which the objective variables is qualitative (neck injured / not injured) has been already conducted by the author. The results have shown that various human attributes influence on the incidence of neck injuries. And the author has also mentioned that there is a possibility that the health consciousness of the parties involved influences whether some injuries are reported or not.

This time, the analysis in which the number of treatment days of the injuries as a continuous variable is focused on is conducted so as to minimize the influence of the health consciousness of the parties involved. Moreover, the delta-V of a struck vehicle is considered in this analysis so that the influence of impact severity in a rear-end collision can be eliminated. As a result, the analytical quality about the influence of human attributes such as gender, age, generation and trip purpose on the injury severity is improved, and the further detailed information about the influence can be obtained.

The data to be used in this analysis are from the accident database which Tokyo Metropolitan Police Department offered to ITARDA for this study and from the in-depth accident database which ITARDA constructed. The analysis based on the number of treatment days is possible by using these databases.

Paper No. 07-0486-O
Review Of Existing Injury Criteria And Their Tolerance Limits For Whiplash Injuries With Respect To Testing Experience And Rating Systems
Klaus Bortenschlager, *Partnership for Dummy Technology and Biomechanics (PDB)*
Markus Hartlieb, *DaimlerChrysler AG*
Karl Barnsteiner, *BMW AG*
Leonard Ferdinand, *Dr. Ing. h.c. F. Porsche AG*

Technical Session: Rear Impact Injury Prevention

David Kramberger, *Audi AG*
Sven Siems, *Volkswagen AG, Germany*
Markus Muser, *AGU Zurich*
Kai-Uwe Schmitt, *AGU Zurich and ETH Zurich, Switzerland*

Abstract:
In the recent years, a large effort has been directed towards the investigation of injury mechanisms and injury tolerance criteria related to whiplash associated disorders (WAD). Nevertheless, many questions, especially related to injury criteria and their respective biomechanical tolerance levels, remain unresolved.

With the advent of consumer tests in which the protection potential of seats against WAD is evaluated, a discussion of the criteria used for these ratings is needed, since for most proposed WAD injury criteria, e.g. NIC, Nkm, LNL, no widely accepted tolerance levels, let alone accurate injury risk curves, are available today. One of the often disregarded points in the tolerance limit discussions is the fact that most injury criteria values have a non-linear relation to injury risk. Many tolerance levels for criteria related to injuries other than WAD (such as HIC, Nij, TTI, Gambit, TI etc.) were derived using highly non-linear logistic regression curves. The biomechanical loads discussed in conjunction with WAD, e.g. accelerations, forces, moments of torque, are generally very low in comparison to loads acting in other crash situations. Even minor changes in a test set-up may thus result in significant changes in the loads measured. Furthermore, issues of repeatability and reproducibility become more important in these low-load test conditions.

A series of sled tests was conducted to assess the influence of several test parameters on the repeatability and reproducibility of results obtained with the BioRID-IIg. The sled tests were performed according to the test procedures of IIWPG, ADAC and Folksam. The results of four BioRID-IIg dummies were compared with each other. The results of these tests are discussed with respect to various proposed injury criteria, especially in view of the rating systems currently in discussion. Finally, a more generalised approach to rating scales, taking into account the issues mentioned above, is proposed.

Paper No. 0-0437-O

A Multi-Body Model Of The Whole Human Spine For Whiplash Investigations

Volkan Esat, Memis Acar, *Loughborough University, United Kingdom*

Abstract:
Whiplash is a very common injury of the cervical spine, occurring usually as a result of low speed, rear-end car crashes. Whiplash not only leaves some patients with severe residual disability that may interfere with their ability to do their job and quality of life, but also burdens the economy with a huge cost. In this context, biomechanical modelling and simulation have been of essential importance for investigating whiplash as a powerful alternative to cadaver and dummy tests.
This paper presents whiplash simulations and analyses under various impact conditions and acceleration levels by employing a rigorously validated biofidelic multi-body (MB) model of the whole human spine. The novel MB model possesses highly advanced material properties such as viscoelastic behaviour, active-passive muscles, and geometric nonlinearities. The main advantage associated with the model lies

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in incorporating the whole spinal components such as vertebrae, ribs, muscles, intervertebral discs, and ligaments, which helped to simulate and validate more realistically. Validation was carried out comparing the motion segment responses, the MB model responses for frontal and lateral impacts, the vertical loading results, and the responses of thoracolumbar region in rear-end impact. The model successfully reproduced the characteristic motion of the head and neck when subjected to rear-end crash scenarios. Whiplash simulations conducted involve not only the responses of the ligamentous spine model, but also predictions of the model with active/passive musculature. The MB model simulation results and model predictions such as head translations and rotations, muscle and ligament forces, and intervertebral angles showed good agreement with experiments. The study is limited to presenting the kinematics and kinetics of the cervical spine. Further investigations on failure of soft tissue components were not conducted. However, the biofidelic whole human spine model proved to be a highly capable and versatile platform to simulate various traumatic whiplash injury situations.

Paper No. 07-0093-O

Consideration Of Possible Indicators For Whiplash Injury Assessment and Examination Of Seat Design Parameters Using Human FE Model

Yuichi Kitagawa, Tsuyoshi Yasuki, Junji Hasegawa, *Toyota Motor Corporation, Japan*

Abstract:

A parametric study was conducted using a human FE model to examine the effects of seat design parameters on the whiplash injury risk predicted by the model. The injury risk was assessed using a widely used indicator NIC and strain in the facet joint capsule that had been focused as a potential site of neck pain in actual scenes. Owing to the precise modeling of the neck soft tissues, the strain was calculated from the elements representing the facet joint capsules. Parameters were selected from major seat design factors that were assumed to contribute to mechanical responses of the seat structure against rearward forces from the occupant body in rear impacts. The study revealed that the rotational stiffness of the reclining joint and the torsional stiffness of the upper-end of the seat back frame were the significant factors for the injury indicators. It was also shown from the results that the NIC value was determined by both the initial acceleration level at T1 and the contact timing of the head to the head restraint, while the joint capsule strain was well correlated with the rotational angle of the head with respect to the torso developing in the later phase of impact. If the initial difference in acceleration between the head and torso was the dominant factor for whiplash injuries, NIC was thought to be a good indicator for injury assessment. Assuming that the neck pain was generated in the facet joint capsules, however, the rotational angle of the head with respect to the torso could be a more realistic indicator to estimate the risk of whiplash injury. Although the current dummies do not directly output such data in electric format, the bending moment at T1 around the lateral axis could be an alternative indicator for injury assessment tests.

Paper No. 07-0264-O

The Study For Static And Quasi-Dynamic Evaluation Method For Assessing Whiplash-Associated Disorder In Rear Impact

Hiroyuki Asada, *Mitsubishi Motors Corporation*

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Katsumi Nawata, *Toyota Motors Corporation, Japan*

Abstract:
Appropriate static (height of head restraint and backset) and quasi-dynamic (dynamic head rotation angle of Hybrid III dummy and dynamic backset) seat & head restraint evaluation method for assessing whiplash-associated disorder in rear impact are studied in JAMA.
On various types of seats, the following items were evaluated about each index: i) correlation thereof with road accident & whiplash phenomenon, ii) reproducibility and repeatability thereof, iii) correlation thereof with dynamic evaluation results on BioRID2, iv) fairness thereof to various seat types. The results showed new findings as follows:
1) As for height of head restraint, if securing the height of head CG + the rumpling up, further increase in height does not provide much support for reduction in injury.
2) As for backset, due to poor reproducibility in measurement on conventional HRMD, a new measuring method on the basis of SRP is effective. Decrease in backset contributes to injury lessening, however, since excessive small backset deteriorates comfort, achieving balance of safety and comfort was examined.
3) As for dynamic head rotation angle of neck of Hybrid III dummy, because of poor biofidelity of the dummy, the angle is difficult to be considered as proper dynamic evaluation, however, thanks to good reproducibility and repeatability of the dummy as well as some correlation between head rotation angle and injury criteria, the angle is available as a tool for alternative evaluation of the backset.
4) Dynamic backset was proposed as an alternative test to static backset. However, the evaluation uses only neck behavior of the dummy, in addition, reproducibility and repeatability are still low. Consequently, the backset cannot be regarded as an appropriate evaluation method at this time.

Paper No. 07-0366-O

Comparing Dummy Responses In Head Restraint Performance Assessment

Michael Kleinberger, Liming Voo, Rafal Szczepanowsk, Andrew Merkle, Bethany McGee, *Johns Hopkins University Applied Physics Laboratory, United States*

Abstract:
Whiplash injuries and their associated cervical symptoms are a critical problem resulting from rear impact motor vehicle collisions.
Although the exact injury mechanisms remain elusive, recent biomechanical research have suggested that relative motion between the head and torso, or more precisely between adjacent vertebrae of the neck, may be the primary cause for such injuries. Currently available test dummies have limited biofidelity and functionality in the assessment of head restraint performance. The challenge to the automotive safety community is to select a dummy that is capable of differentiating good seat and head restraint design features from bad ones in terms of their whiplash injury mitigation. The objective of this study was to investigate the ability of various dummies to distinguish between good and bad designs under well-controlled rear impact sled testing conditions. Four currently available 50th-percentile male dummies, namely Hybrid III, THOR, BioRID II, and RID III, were used. Seat and head restraint design features studied included recliner stiffness, head restraint height, and head restraint backset using a modified stock automotive seat. A variety of biomechanical measurements for whiplash injury risk were

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used in the assessment of head restraint performance, including dummy kinematics. Results indicated significant differences between the dummy responses and their sensitivities to distinguishing various seat and head restraint design features.

Paper No. 07-0041-O

Dynamic Performance Of Active Head Restraints

Liming Voo, Bethany McGee, Andrew Merkle, Michael Kleinberger, *Johns Hopkins University Applied Physics Laboratory*
Shashi Kuppa, *National Highway Traffic Safety Administration, United States*

Abstract:
Active head restraints may perform better dynamically than their static geometric characteristics would indicate. Farmer found that active head restraints that move higher and closer to the occupant's head during rear-end collisions reduced injury claims rates by 14-26 percent. NHTSA published the FMVSS No. 202a final rule on head restraints in December, 2004 to help reduce whiplash injury risk in rear collisions. The final rule provides an optional dynamic test to encourage continued development of innovative technologies for whiplash injury mitigation, including those that incorporate dynamic characteristics of occupant-seat interactions. This study evaluates a select number of OEM seats with active head restraints in the FMVSS 202a dynamic test environment. The rear impact tests were conducted using a deceleration sled system with an instrumented 50th percentile Hybrid III dummy. Seat performance was evaluated based on several proposed biomechanical measures to assess neck injury risk. The relative dynamic positions between the head and the head-restraint were also analyzed and compared to their initial (static) positions.

Paper No. 07-0201-O

Assessing The BioRID II Repeatability And Reproducibility By Applying The Objective Rating Method (ORM) On Rear-End Sled Tests

Linda Eriksson, *Autoliv Sverige AB, Sweden*
Harald Zellmer, *Autoliv B.V. & Co. KG, Elmshorn, Germany*

Abstract:
The BioRID II seems to be the most biofidelic dummy for low-speed rear-end crash tests and is therefore included in several proposed test methods. However, to be broadly accepted, the repeatability and reproducibility of the BioRID II must be verified.

This study aims to assess the BioRID II repeatability and reproducibility by applying the Objective Rating Method (ORM) on rear-end sled tests. The ORM, published by Hovenga et al. (2005), compares crash tests in terms correlations between criteria, peak values, peak-value times, or curve shapes. Correlations are calculated for all dummy readings and criteria, and for the complete dummy. Here, the sled tests evaluated were conducted at two crash-test sites; three BioRID II dummies were seated in different kinds of seats and exposed to three crash pulses. The analysed data contained criteria and dummy readings.

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It was found that the BioRID II repeatability, in terms of ORM-values, was above 90% for most criteria, peak values and peak value occurrence times. The curve shape correlations were, with few exceptions, much above 65%. Furthermore, there were only minor differences in repeatability from various test sites, dummies, pulses, and seats. The repeatability for the complete BioRID II was found to range between 81 and 87%. The BioRID II reproducibility was somewhat lower, around 75%. Based on component tests with the Hybrid III, TNO/TASS has proposed 65% as the level for good correlation.

It can be concluded that the BioRID II shows good repeatability and reproducibility for all compared crash conditions. Furthermore, the BioRID II shows excellent repeatability for nearly all of the criteria typically included in the proposed test procedures.

Paper No. 07-0468-O

Real-Life Performance Of Whiplash Seats And Correlation Between Whiplash Consumer Ratings And Real-Life Crashes

Anders Kullgren, Maria Krafft, *Folksam Research, Karolinska Institutet*
Anders Lie, *SRA, Karolinska Institutet*
Claes Tingvall, *SRA, Monash University, Sweden*

Abstract:
The objective was to study the influence of various types of car seats, aimed at protecting whiplash injuries, on real-life injury outcome. Furthermore, the aim was to study correlation between whiplash consumer ratings and real-life injury outcome. In both cases the influence on long-term whiplash injuries were studied.

Since 1998 various seats aimed at protecting whiplash injuries have been introduced in cars. The cars were divided into 4 groups according to the safety technology used. Since 2003 consumer rating programmes have been running. The performance on group level of the test results of the Folksam/SRA ratings in Sweden and the IIWPG ratings were studied.

Preliminary results show that the Volvo Whips seat and the Saab SAHR seat reduce the incidence of whiplash injuries with long-term consequences with approximately 40%. In general a good correlation was found between consumer ratings and real-life outcome. Preliminary results indicate that cars performing well in the IIWPG and Folksam/SRA ratings have 50% lower risk of long-term consequences in real-life crashes than a group of cars not performing well or not fitted with a whiplash protection system.

A limitation with the tests is that the consumer rating programmes are conducted with the seat only, while the real-life injury outcome concerns the performance of the whole car.

It can be concluded that seats aimed at preventing whiplash injuries in general also lower the risk in real-life crashes. Furthermore it can be concluded that results from existing consumer rating programmes correlate with real-life injury outcome.

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The performance of recent introduced whiplash prevention technology is very important for future activities in legislation and consumer testing, such as EuroNCAP. The correlation between real-life whiplash injury outcome and consumer rating results has not been shown in previous studies.

Paper No. 07-0315-O

Application Of Rear Row Head Airbag To Mitigate Rear Impact

Jörg Hoffmann, *Toyoda Gosei Europe NV, Germany*
Shigeyuki Suzuki, Masaya Sakamoto, Kenji Hayakawa, *Toyoda Gosei Ltd., Japan*

Abstract:
In real world accident the ratio of the rear impact is high. The injury scheme in those accident scenarios is mainly caused by whip plash. The intrusion of the vehicle rear end during the impact in combination with the occupant movement seated on rear seats plays a significant roll. The paper presented will discuss an airbag which deploys from the roof header along the rear window. By numerical simulations and tests the mitigation of biomechanical injuries of passengers, seated on rear seats during rear impact, were observed. A significant occupant protection was assessed under high speed rear impact conditions.

Paper No. 07-146-O

Development Of Rear Pre-Crash Safety System For Rear-End Collisions

Kiyoka Matsubayashi, Yukinori Yamada, Motomi Iyoda, Shin Koike, Tomoya Kawasaki, Masanori Tokuda, *Toyota Motor Corporation, Japan*

Abstract:
Pre-crash safety systems using a radar detecting technique have been developed to reduce impacts and injuries for frontal collisions. Those systems have been focused on the frontal collisions. But rear-end collision are responsible for a high proportion of traffic accident injuries. A new pre-crash safety system for rear-end collisions has been developed to promote awareness to a vehicle approaching from behind and reduce the whiplash injuries. This new system uses millimeter-wave radar installed in the rear bumper to detect a vehicle approaching closely from behind. If it is determined that there is a risk of collision, the hazard lights flash to warn the driver of the rear vehicle and a headrest moves forward. Furthermore, sensors in the headrests detect the location of the occupants of heads and reduce the risk of whiplash injury by shifting the headrests to a suitable position before the collision occurs. This paper shows the effects of pre-crash hazard light and pre-crash headrest.

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Technical Session: Improved Safety for Pedestrians and Other Vulnerable Road Users

Oral Presentations | Wednesday, June 20, 2007 | 1:00p.m.-5:30p.m.

Chairperson: Yoshiyuki Mizuno, Japan | Track A |
Room: Salle Rhône 3
Co-Chairperson: Ekkehard Brühning, Germany

Paper No. 07-0177-O
APROSYS European In-Depth Pedestrian Database
Emma Carter, Clive Neal-Sturgess, BASC - *University of Birmingham*
Roger Hardy, *Cranfield University*
Richard Cuerden, *TRL Ltd, United Kingdom*
Luis Guerra, *Univeristy of Madrid, Spain*
Jikuang Yang, *Chalmers University, Sweden*

Abstract:
Research question/objective:
The EU FP 6 Integrated Project on Advanced Protection Systems (APROSYS) is to explore the relevance of vehicle pedestrian protection systems in the real world.

Methods: A pedestrian injury database was compiled of in-depth information to permit reconstructions of the pedestrian/cyclist/vehicle/ground interactions.
Data sources (include sample size)
In-depth pedestrian injury data was contributed by: the Birmingham Automotive Safety Centre, TRL Ltd Crowthorne, INSIA, Madrid, Chalmers University and the Daimler Chrysler Corp. The database consisted of 63 pedestrians and 7 cyclists.

Expected Results: Results were obtained on: injury risk as related to impact speed; the locations of primary head impacts with vehicles; the proportion and frequency of ground impacts; the over representation of elderly fatals with MAIS3.

Conclusions: It is concluded that (i) the head impact locations for pedestrian protection need to be reviewed to include the windscreen, A pillars and scuttle areas, and (ii) a calibration of MAIS and ISS against fatality/non fatality for a large sample of pedestrians is necessary, with the elderly (>60 years of age) ranked separately.

Discussion: The locations of primary head impacts with vehicles were identified and lay principally on the windscreen, scuttle and A-pillar. Child head impacts were also identified in these regions. The frequency of secondary impacts were found to be more important for children than adults, and particularly important for cyclists; although the sample sizes were small. There was a considerable over representation of elderly fatals at MAIS3 than would be expected from population studies conducted on vehicle occupants.

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Limitation of study
Sample size, and appropriate injury risk functions.
What does the paper offer that is new in the field?
Identifies the windscreen/A pillar/Scuttle areas for head impacts, and shows that the elderly vulnerable road users are more at risk than indicated by general vehicle occupant studies.

Paper No. 07-0417-O

A Comparison Study On Vehicle Traffic Accident And Injuries Of Vulnerable Road Users In China and Germany

Jikuang Yang, *Hunan University, Peoples Republic of China*
Dietmar Otte, *Medical University of Hannover, Germany*

Abstract:
The vehicle traffic accidents and injuries are common problem worldwide. Even though the vehicle traffic accidents have been widely studied in different countries, but the difference of nature of traffic accidents in different countries was not adequately investigated for set suitable protective strategy in different area. This study aimed to identify the occurrence, type and mechanisms of the traumatic injuries of the vulnerable road users in vehicle collisions in China and Germany.
The 1300 Chinese accident cases and 800 German cases (in the years 2000 to 2005) were collected from traffic police, hospital in Changsha and Medical University Hannover, respectively. An in-depth study was carried out based on the collected accident data by using approaches of statistics analysis and virtual reconstructions. The results from analysis of Chinese data were compared with results from analysis of German data.
The injury severities were determined using AIS code and ISS values. The results were presented in terms of cause of injuries, injury distributions, injury patterns, injury severity. The pedestrian accidents were identified as vital issue in urban traffic safety and therefore a high priority should be given to this road user group in research of safe urban transportation.
It was discussed with regard to accident data collection, accident sampling and injury distributions, the factors influenced the injury outcomes etc.
The data sources reflects the real situations of vulnerable road users in traffic accidents in Changsha and Hannover and may not in the whole countries of China and Germany.
This study will contribute to the determination of different nature of vehicle traffic accidens between motorized and motorizing areas, which will form a firm background for making safety counter-measures.

Paper No. 07-0176-O

Relevance On Injury Causation Of Vehicle Parts In Car To Pedestrian Impacts In Different Accident Configurations Of The Traffic Scenario And Aspects Of Accident Avoidance And Injury Prevention

Dietmar Otte, *Medical University Hannover Accident Research Unit*
Tobias Huefner, *Medical University Hannover Department of Trauma Surgery, Germany*

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Abstract:
1090 car to pedestrian accidents from GIDAS (German in-Depth-Accident-Study) are analyzed, documented in 1999 to 2004 by a scientific team of the Medical University Hanover and the Technical University Dresden. The accident investigations are conducted according to a statistic random sampling and integrated statistic weighting procedure of data set, the results are representative. This new study executed here covers the analysis of the injury situation of the pedestrian in different accident situations of the traffic scenarios on different places of the road network.
For the purpose all accidents were allocated to a detailed classification of types of accidents related to the infrastructure of road conditions and protection devices like crosswalks and traffic signs. For these different road conditions the resulting injuries were evaluated. Accidents at intersections, when using crosswalks and at traffic lights were analyzed regarding the respective levels of severity. Based on the knowledge of the reconstruction of traces on the road the impact and driving velocities of the cars were determined for all the cases, avoidance strategies were postulated and aspects of possible avoidance of the accident by the driver of the car were discussed. Also the sources of injuries at the vehicle outer shell receive a special weighting in the view of the different accident configurations. From the comprehensive reconstruction of each accident the temporal prevention time period could be calculated, which could be stated for today's vehicles for the conversion of a technical implementation of prevention sensors.
The study points out how the pedestrians were impacted under these different conditions and which speed and injury situation occurred and improves different safety countermeasures. The highest injury severity could be found on junctions and stretched streets when they are not well protected.

Paper No. 07-0273-O

Pedestrian Reconstruction Using Multibody Madymo Simulation And The Polar-Ii Dummy: A Comparison Of Head Kinematics

Robert Anderson, Luke Streeter, Giulio Ponte, Jack McLean, *University of Adelaide, Australia*

Abstract:
The aim of this study was to reconstruct three pedestrian collisions using the computer program MADYMO, the EEVC sub-system impactors and the POLAR II dummy. In this paper we compare the head kinematic and impact results from each of these techniques with reference to the pedestrians' head injuries. We also discuss aspects of the reconstructions made using these different tools, especially findings on the velocity trajectory of the head. The cases were ones in which the pedestrian's height and weight were close to the 50th percentile adult human male, and where the accident investigation provided good estimates of impact speed and complete injury data. The cases were reconstructed to estimate the speed of the vehicle at impact and the position of the pedestrian relative to the vehicle. Contact points between the vehicle and pedestrian were recorded. From this information MADYMO simulations were made to estimate the kinematics of the pedestrian during the collision. Each simulation was used to estimate impact conditions between the pedestrian and the vehicle involved. The impact between the head of the pedestrian and vehicle was reconstructed using an EEVC sub-system headform. A car of the

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same model as that involved in the accident was tested with the intention that the structure being struck was the same as that as in the actual accident. In addition to the sub-system tests, we reconstructed each case using the POLAR II full-scale pedestrian dummy. As with the subsystem tests, the same model vehicle was used to strike the dummy. Results indicate some potentially important differences in head trajectory between the dummy and the computer simulation. To our knowledge, this is the first comparison between results of POLAR II and sub-system tests applied to the reconstruction of actual accidents.

Paper No. 07-0328-O

Pedestrian Kinematics Investigation With Finite Element Dummy Models Based On Anthropometry Scaling Method

Costin Untaroiu, Jaeho Shin, Jeff Crandall, Johan Ivarsson, *University of Virginia, United States*
Yukou Takahashi, Akihiko Akiyama, Yuki Kikuchi, *Honda R&D Co., Ltd., Japan*

Abstract:
Previous pedestrian impact experiments using cadavers have shown that factors such as vehicle shape and pedestrian anthropometry can influence pedestrian kinematics and injury mechanisms. While a parametric study examining these factors could elucidate the complex relationships that govern pedestrian kinematics, it would be impractical with cadaver tests due to the relative expense involved in performing numerous experiments on subjects with varying anthropometry. On the other hand, finite element (FE) modeling represents a more feasible approach since numerous experiments can be conducted with a fraction of the expense. This study examined the relationship between pedestrian anthropometry and vehicle shape using a PAM-CRASH model of the 50th percentile male (50th) Polar-II pedestrian dummy extensively validated against experimental data. In order to evaluate the influence of the pedestrian anthropometry on the dummy kinematics, scaled dummy models were developed based on the weight and height data of the 5th percentile female (5th) and 95th percentile large male (95th). Simulations of the 5th, 50th, and 95th Polar-II FE models struck at 40 km/h by a mid-size sedan were used to generate trajectories of the head, upper thorax, mid-thorax, and pelvis. In an effort to assess the validity of scaling techniques when interpreting trajectory data from vehicle-pedestrian crashes, the trajectories of the 5th and 95th model were scaled to the 50th percentile male and compared to those generated with the 50th model. The results demonstrated nonlinear behavior of dummy kinematics that could not be accounted for with traditional height and mass scaling techniques. Thus, estimation of wrap around distances based on pedestrian stature and normalization of experimental cadaver trajectories based on anthropometry were shown to be inaccurate in these simulations.

Paper No. 07-0426-O

Pedestrian Safety Enhancement Using Numerical Methods

Daniel Baumgartner, Daniel Marjoux, Remy Willinger, *University Louis Pasteur Strasbourg, France*
Emma Carter, Clive Neale-Sturgess, *University of Birmingham*
Roger Hardy, *CIC – Cranfield University, United Kingdom*
Luis Guerra, Luis Martinez, *Institute for Automobile Research, Spain*

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Abstract:
This study aims at investigating head injury mechanisms for brain injuries, subdural (SDH) or subarahnoidal (SAH) haematoma and skull fractures in adult pedestrian accidents by in-depth accident analysis and accident reconstruction.

Eight real world pedestrian accidents were carried out using a multi-body system pedestrian and cars models to acquire the head impact conditions such as head impact velocity, position and orientation against the car's bonnet or windscreen. These impact conditions were then imposed on a head, windscreen and bonnet finite element model (FEM) in order to calculate different mechanical parameters that are sustained by each victim during the impact. These calculated head stresses and strains were then correlated with the observed injury patterns, and compared to existing and available head injury mechanisms and tolerance limits.

The accident investigation reports and pedestrian kinematics before the head impact came from the University of Birmingham, INSIA and Daimler Chrysler. They were worked out in the framework of an FP6 Integrated Project on Advanced Protection Systems. The head, the bonnet and the windscreen FEM, the injury mechanisms and tolerance limits have been developed at the University of Strasbourg.

The results show that brain neurological injuries were correlated with brain Von Mises stress. Brain contusions occurred through high brain pressures. Skull fractures and SDH or SAH were correlated with the global strain energy of the skull and of the brain/skull interface respectively.

These results are consistent with other studies using finite elements to reconstruct real world accidents. A correlation between observed injuries and calculated mechanical parameters has to be underlined.

Only eight accident cases have been reconstructed, more cases will be expected to improve the accuracy of these results. Other efforts have to be done to improve the quality of the models in terms of initial impact conditions, geometry and mechanical behaviour.
That study provides new powerful tools to design, evaluate, validate and enhance cars' bonnets and windscreens so as they become less injurious for pedestrians' heads in case of an accident.

Paper No. 07-0429-O

A Comparative Study Between Subsystem And Global Approaches For The Pedestrian Impact

Sophie Chalandon, Patrick Borde, Christian Cotte, *Faurecia*
Thierry Serre, Catherine Masson, Pierre-Jean Arnoux, Christophe Perrin, Christian Brunet, Dominique Cesari, *Institut National de Recherche sur les Transports et leur Sécurité*
François Minne, *Union Technique de l'Automobile, du Motocycle et du Cycle, France*

Abstract:
In order to improve the pedestrian safety during an impact with a vehicle, subsystem tests have been defined to evaluate the aggressiveness of the front-end of cars. These subsystems tests have to be

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reproducible and are representative of the three decomposed impacts of the pedestrian with the car: lower leg on the bumper, pelvis on the hood, head on the hood or the windscreen. The velocity, angle and mass of the adult headform impactor and its impact area are invariable parameters. Upper legform impactor parameters are determined by vehicle characteristics. Lower legform impactor parameters are invariable (velocity and positioning). Nevertheless, these decoupled tests do not take into account the influence of the whole body on impacts. Therefore, it appears important to compare these subsystem tests with global conditions observed in real accident. The objective of this paper is to perform this work on two French vehicles. Concerning the global conditions, four full-scale experimental tests with PMHS and the associating multibody numerical simulations were performed in classical (lateral impact for the pedestrian, centred for the vehicle) and real configurations.
In that way, two real accidents have been chosen in this impact configuration with a velocity value closed to 40 km/h. Each reconstruction of accidents is based on In-Depth Accident Investigation first. Then, a parametric study using multibody models, validated with an experimental test, gives a hypothetic initial configuration of the accident. This configuration is used to put on an experimental reconstruction. Then, results from numerical and experimental studies are compared for the adult headform, the upper legform and the lower legform impacts. Finally, a global comparison is analysed more specifically on injuries not include on the subsystem approach. These injuries are also compared to Accidental Database to know whether their proportion is important or not.

Paper No. 07-0009-O

Evaluation Of The Effects Of Test Parameters On The Results Of The Lower Legform Impactor

Sven Siems, *Volkswagen AG*
Oliver Zander, *BASt*
Dirk-Uwe Gehring, Peter Leßmann, Böhme-Gehring Sicherheit
Karl Barnsteiner, *BMW AG*
Klaus Bortenschlager, *PDB*
Leonard Ferdinand, *Dr. Ing. h.c. F. Porsche AG*
Markus Hartlieb, *DaimlerChrysler AG*
David Kramberger, *Audi AG*
Manfred Zeugner, *Adam Opel GmbH, Germany*

Abstract:
The PDB, BASt and Opel conducted two test series to evaluate possible effects on the results obtained using the EEVC WG17 Lower Legform Impactor as a test tool for the assessment of pedestrian safety.

The reproducibility and repeatability of the test results were assessed using six legform impactors while keeping the test parameters constant.

In the second series one impactor was used and the test parameters were varied to assess the effects on the readings of the legform. The test parameters were velocity, temperature, relative humidity, the point of first contact regarding the deviation in z-direction and the deviations of the pitch, roll and yaw angle.

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The tests were performed using an inverse setup, i.e. the legform was hit by a guided linear impactor equipped with a honeycomb deformation element. This setup was chosen to be able to vary each single parameter while avoiding variations of the other test parameters at the same time. The test parameters were varied stronger than allowed in regulatory use in order to determine possible dependencies between the parameters and the readings which were acceleration, bending angle and shear displacement.

Paper No. 07-0178-O

Development Of A Biofidelic Flexible Pedestrian Legform Impactor GT (Flex-GT)

Atsuhiro Konosu, Takahiro Issiki, *Japan Automobile Research Institute*
Masaaki Tanahashi, Hideki Suzuki, *Japan Automobile Manufacturers Association, Inc., Japan*

Abstract:
The Japan Automobile Research Institute and the Japan Automobile Manufacturers Association, Inc., have been developing a biofidelic flexible pedestrian legform impactor (Flex-PLI) since 2002. Flex-PLI has flexible long bones like human bones and is equipped with many sensors to evaluate the severity of pedestrian lower extremity injuries in multiple locations.

In this study, we developed a biofidelic flexible pedestrian legform impactor GT (Flex-GT) to improve the injury assessment ability, usability, and durability of Flex-G.

This paper presents the detailed Flex-GT specifications, development processes, and several test results for checking its performances.

Paper No. 07-0206-O

Prediction Of Lower Extremity Injury Risks During An Impact On Modern Car Fronts With A Flexible Pedestrian Legform Impactor And The Pedestrian Legform Impactor According To EEVC WG 17

Oliver Zander, Bernd Lorenz, *Federal Highway Research Institute (BASt)*
Dirk-Uwe Gehring, Peter Leßmann, *BGS Boehme & Gehring, Germany*

Abstract:
A legform impactor with biofidelic characteristics (FlexPLI) which is being developed by the Japanese Automobile Research Institute (JARI) is being considered as a test tool for legislation within a Global Technical Regulation on pedestrian protection (GTR) and therefore being evaluated by the Technical Evaluation Group (TEG) of GRSP. In previous built levels it already showed good test results on real cars as well as under idealised test conditions but also revealed further need for improvement.

A research study at the Federal Highway Research Institute (BASt) deals with the question on how leg injury risks of modern car front shapes can be revealed, reflected and assessed by the FlexPLI and how the impactor can be used and implemented as a legislative instrument for the type approval of cars

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according to current and future legislations on pedestrian protection. The latest impactor built level is being evaluated by a general review and assessment of the certification procedure, the knee joint biofidelity and the currently proposed injury criteria. Furthermore, the usability, robustness and durability as a test tool for legislation is examined and an assessment of leg injuries is made by a series of tests with the FlexPLI on real cars with modern car front shapes as well as under idealised test conditions. Finally, a comparison is made between the FlexPLI and the current legislation tool, the legform impactor according to EEVC WG 17.

Paper No. 07-0271-O

Development Of A Pedestrian Legform To Assess Sensors Used In Active Pedestrian Protection Systems

James Manning, *TRL Ltd., United Kingdom*

Abstract:

This paper reports on the development of a new legform to test contact sensors of active safety systems that could be used to deploy pedestrian protection systems. To test the systems accurately a test tool is required with properties that are as close as possible to human responses.

Current legforms were not designed to test sensors but were designed to assess passive protection by imparting a concentrated force to selected parts of the vehicle. Due to the characteristics of the legform it is believed that the bumper sensor threshold could be set too high, causing a late deployment or even preventing the active system from deploying. The possibility of serious or life threatening head injuries occurring could be increased if the active system does not deploy as intended.

To achieve a better force distribution on the bumper sensors, the revised impactor needs to be as biofidelic as possible. Data on the mechanical properties of human bone and flesh have been researched and materials selected to provide the most realistic response, during a vehicle to pedestrian impact. The purpose of the impactor is to assess contact sensor technology that could be used in active safety pedestrian systems to distinguish an impact between a vehicle and a pedestrian and a vehicle and another object.

The paper reviews the legform design specification in terms of its requirements and biofidelic data. Through finite element modelling the use and limits of the test tool with regard to bumper reference height and the use of an upper body mass are discussed. The paper also presents the preliminary test results of the sensor legform and the validation of the results with the initial design targets.

Paper No. 07-0313-O

Pedestrian GTR Head Testing Of Current Vehicles

Ann Mallory, Transportation Research Center
Jason Stammen, Susan Meyerson, *National Highway Traffic Safety Administration, United States*

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Abstract:
Research Question: Are current vehicles sold in the United States able to meet the GTR pedestrian head test requirements? If all vehicles were required to meet the GTR pedestrian head test requirements, would pedestrian safety be improved? Is the proposed standard applicable to heavier vehicles and high-front light trucks and vans?

Method: A series of GTR head tests were performed on a selected group of vehicles at various points on the front structures. Tested vehicles had a wide range of gross vehicle weights and hood leading edge heights. The HIC values were calculated, tabulated and summarized.

Data Sources: All testing and data were obtained from vehicle front structure testing at the Vehicle Research and Test Center of NHTSA.

Expected Results: Test results are expected to demonstrate that some vehicles already meet the proposed GTR test requirements and that other vehicles do not meet those requirements. Modifications to the front structures of those vehicles that do not currently meet the GTR requirements could result in increased pedestrian safety benefits.

Conclusion: Some vehicles already appear to meet the criteria of the current pedestrian GTR. The test results and analysis in this paper will provide an assessment of the potential benefits if the vehicles that do not currently meet the GTR criteria, were required to do so.

Paper No. 07-0380-O

Injury Mitigation In SUV To Pedestrian Impacts

Rikard Fredriksson, Ola Boström, Erik Flink, Kenneth Backman, *Autoliv Research, Sweden*

Abstract:
In passenger car to pedestrian impacts head and leg injuries account for the largest number of severe injuries (AIS 3+). Longhitano et al (2005) confirmed this but when comparing with LTV type of vehicles (for US data), thorax injuries replaced leg injuries at 2nd place for AIS 3+ injuries. For passenger cars the hood edge contributed to very few injuries, while in the LTV vehicles it was the main contributor for both lower extremity as well as thorax injuries. It is likely that the lower extremity injuries mainly consist of pelvic injuries, and that the hood edge (also called bonnet leading edge or BLE) of large SUVs (Sport Utility Vehicles) produce more thorax injuries while lower SUV hood edges produce more pelvic injuries. The recent development of pre-crash sensors has opened up new possibilities for pedestrian protection. Slower reversible solutions can be used as well as airbags in the very front of the car.
A bonnet leading edge airbag was developed to mitigate pelvis and thorax injuries. A Ford Explorer was used in the study. In mathematical simulations the airbag was designed to decrease the upper legform requirements below the threshold levels of EuroNCAP. It was then tested with side airbag dummies at 40 km/h to study the pelvic and thoracic loadings. The THUMS pedestrian model was used to evaluate pelvic and thoracic loadings as well as the head impact speed.

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The BLE airbag decreased force and moment of the upper legform and the pelvic and thoracic loadings. It also influenced the impact speed of the pedestrian head impacting the hood.
The study is limited to one SUV model, but by varying the height of the impacting dummy as well as the stiffness of the bonnet leading edge it is likely to cover a wider variety of SUV vehicles.

Paper No. 07-0467-O

Effect Of Vehicle Design On Head Injury Severity And Throw Distance Variations In Bicycle Crashes

Manvinder Singh, Rohit Dey, Sudipto Mukherjee, Anoop Chawla, Dinesh Mohan, *Indian Institute of Technology, Delhi, India*

Abstract:
The variation of the throwing distance and Head Injury Criterion (HIC) values with car velocity, point of impact and angle of approach has been studied for bicycle impact with three different categories of vehicles- small cars, sports utility vehicles (SUV) and buses. Crashes were simulated using multi body models developed in MADYMOTM. The Hybrid III 50th percentile male dummy model, available from MADYMO library has been used. Crash configurations reported in literature have been used and parametric variations have been done in speed, angle of approach and point of impact. The variation in the angle of approach or point of contact causes significant changes. The trends in the front-to-side impact follow reconstructed data reported by Otte (2002) and the large spread seen in reconstruction is predicted to originate from variation in the impact configuration. The changes in the trends can be associated with key changes in the nature of the impact visible in the simulations (head impacting car, no impact of rider with car etc.). The kinematics of impact in case of the bus has significant differences and this leads to variation in the nature of correlations. The HIC values were predicted to be higher in the case of bus as compared to the SUV and the small car. For bicycle crash reconstruction, the impact configuration in addition to the throw distance has to be used to arrive at the impact v. The paper also gives data which when populated further could form a basis of such reconstructions.

Paper No. 07-0198-O

The Study On Developing Active Hood Lift System For Decreasing Pedestrian Head Injury

Keun Bae Lee, Han-Jo Jung, Han-Il Bae, *Hyundai Motors, Republic of Korea*

Abstract:
Up to recently severe pedestrian injury and death cases are seldom decreased because the structure of vehicles are increasingly stiffened to protect the driver and passenger. To overcome this problem, in this study the active hood lift system is developed composed of detecting sensor, algorithm, ECU and the actuator which lifts the hood. The operating time and the function of the discrimination of the pedestrian during impact are checked out after the developed system is integrated into the vehicles. Finally, the distinct decreasing of child headform injury could be identified through the EURO-NCAP headform tests and CAE simulations.

Technical Session: Improved Safety for Pedestrians and Other Vulnerable Road Users

Technical Session: Improved Safety for Pedestrians and Other Vulnerable Road Users

Technical Session: Biomechanics: Injury Criteria and Test Procedures

Oral Presentations | Wednesday, June 20, 2007 | 1:00p.m.-5:30p.m.

Chairperson: Jean-Pierre Verriest, France | Track C | Room: Salon Pasteur
Co-Chairperson: Suzanne Tylko, Canada

Paper No. 07-0043-O
NHTSA's Vision For Human Injury Research
Stephen Ridella, Shashi Kuppa, Peter Martin, Catherine McCullough, Rodney Rudd, Mark Scarboro, Erik Takhounts, *National Highway Traffic Safety Administration, United States*

Abstract:
The Human Injury Research Division at NHTSA has a mission to conduct research to advance the scientific knowledge in impact biomechanics that enhances motor vehicle occupant safety and supports NHTSA's mission to save lives, prevent injuries, and reduce economic costs due to road traffic crashes. For over 25 years, NHTSA's research has helped to understand better the mechanisms of human injury and the tolerance of the various regions of the human body to the mechanical forces as a result of a car crash. The crash dummies, injury criteria, and modeling tools developed under this research have enabled the agency to develop regulations and consumer information to make vehicles safer.

This paper will describe how analysis of crash field data and in-depth case analysis has helped to identify vulnerable populations of occupants as well as areas of the human body that require further research. Injury tolerance of the elderly, pediatric biomechanics, head and brain injury, and thoracic and abdominal injuries are examples of the projects that will be described. The use of advanced computer modeling techniques for assessing human injury and enhancements to current and future crash dummies will be discussed. Finally, a framework for carrying out this research plan will be shared with the intent to stimulate future ideas and collaborations.

Paper No. 07-0050-O
Computational Analysis Of Real World Crashes: A Basis For Accident Reconstruction Methodology
Vikas Hasija, *Gesac*
Erik Takhounts, Stephen Ridella, *National Highway Traffic Safety Administration, United States*

Abstract:
Computerized accident reconstruction analysis is a tool used to investigate the accident sequence and to study occupant kinematics during the crash. This paper focuses on the accident reconstruction methodology by estimating the errors introduced in the reconstruction analysis as a result of the assumptions made due to lack of data availability and other uncertainties. Then mathematical models are used to show the sensitivity of their results, i.e. occupant kinematics, injury predictions, etc. to changes in

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these assumptions. For this analysis, real world crashes involving occupants with and without brain injuries were selected from the Crash Injury Research and Engineering Network (CIREN) database and reconstruction was carried out using the information available from these crashes. The crash pulse from these cases was obtained using Human-Vehicle-Environment (HVE) and then applied to a MADYMO/GATB occupant simulation model of the case vehicle and occupant. Head acceleration output from the model subsequently served as an input into the NHTSA-developed SIMon finite element head model and used to compute probabilities of various brain injuries. The results of the SIMon predictions were then compared to the actually observed brain injuries. Sensitivity analysis was carried out at each step with respect to various assumed parameters starting from generation of collision pulse in HVE and ending with SIMon brain injury predictors. Important parameters required for better injury prediction were also identified and recommendations to the CIREN accident investigation team are made. This paper thus shows the methodology to be followed, the important details to be taken into account and the additional information that needs to be collected from the real world crashes for accurate accident reconstruction analysis.

Paper No. 07-0300-O

Use Of MADYMO's Human Facet Model To Evaluate The Risk Of Head Injury In Impact

Bertrand Fréchède, Andrew McIntosh, *The University of New South Wales, Australia*

Abstract:

MADYMO rigid-body models are widely used in the automotive industry for a range of occupant protection related applications. These models have been evaluated at various levels against a range of experimental conditions including blunt impacts.

To date the greatest focus for head impacts has been the study of severe impacts. It appears beneficial to broaden the field of validation of these models, and to expand the knowledge of tolerance limits associated with lower severity injury. In this case, mild traumatic brain injury (MTBI).

A simulation protocol was developed using MADYMO's human facet models to reconstruct 27 real-life concussive head impacts from impact sports. The cases were selected from a set that had been studied using a video analysis protocol. The contact behaviour of the model was first evaluated against both experimental and numerical results available in the literature. The video impact cases where then reconstructed and simulated, allowing the assessment of a range of global biomechanical parameters that have been shown to be correlated with injury risk.

The reliability of these reconstructions was evaluated by means of a sensitivity analysis of the influence of several independent variables on these dynamical outputs.

The results showed that the use of MADYMO's human facet model was adequate to obtain a representative estimate of head dynamics in the case of soft to medium impacts. They also confirmed the model's limitations to accurately model short impact durations impacts.

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The following mean peak values for MTBI were obtained from the reconstruction of the real-life impacts: 103 g for the head centre of gravity linear acceleration, 8022 rad/s2 for the head angular acceleration and 359 for the HIC.

These values compare well with other studies and should contribute to the identification of the level at which injury first occurs.

Paper No. 07-0227-O

Development Of Generalized Linear Skull Fracture Criterion

Philemon Chan, Zi Lu, Paul Rigby, *L-3Com/Jaycor*
Erik Takhounts, *National Highway Traffic Safety Administration*
Jiangyue Zhang, Narayan Yoganandan, Frank Pintar, *Medical College of Wisconsin, United States*

Abstract:
The objective of this work is to develop a generalized linear skull fracture criterion for frontal and lateral impacts. At present, a single Hybrid III-based Head Injury Criterion (HIC) is the standard for protection against generalized head injury in a frontal car crash. Vander Vorst, et al (2003 AAAM) developed a linear skull fracture criterion for frontal impact using data mostly from Hodgson and Thomas (1971, 1973) and idealized head model simulations. Vander Vorst, et al, (2004 AAAM) further presented a lateral skull fracture criterion using new post mortem human specimen (PMHS) data and anthropomorphic finite element model simulations. Considerable new PMHS data has also been collected since 2004. Analysis shows that a generalized skull fracture criterion for frontal and lateral impacts can be unified. The integrated data set consists of 63 PMHS samples and 176 drop tests. To unify the analysis and criteria, the latest anthropomorphic finite element model is used to calculate skull strain for all the frontal and lateral PMHS drop tests. The generalized skull fracture criterion is established using logistic regression (Hosmer-Lemeshow, 1989) of the calculated peak skull tensile strain against fracture data. The calculated peak skull strain is also found to correlate with the averaged Hybrid III headform acceleration over the HIC time interval with excellent goodness-of-fit. The results show that it is critical to include the effects of contact area for predicting skull fracture over a wide range of target compliance. This study is limited to linear fracture. This paper provides a biomechanically validated generalized criterion for predicting linear skull fracture with well-defined confidence band.

Paper No. 07-0385-O

A Parametric Study Of Energy Absorbing Materials For Head Injury Prevention

Svein Kleiven, *Royal Institute Technology, Sweden*

Abstract:
This paper describes a parametric study of foam and honeycomb material properties for padding used in interior car surfaces using finite element calculations. Four different head models were used for the impact simulations, a Euro-NCAP dummy head, a Hybrid III dummy head and two biomechanical head models exhibiting different mechanical properties for the brain tissue. The objective was to study the head

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injury criterion (HIC), the head impact power (HIP), the angular acceleration, the angular velocity, the resultant contact force and, for the human head models, the strain in the brain tissue for a variation in material properties such as stiffness, plateau stress and energy absorption. An investigation was also conducted of the kinematics of the head models during impact, evaluating the energy distribution and the apparent mass. The analysis gave at hand that the best choice of material properties with respect to impact using the Euro-NCAP and Hybrid III head models reached substantially different results compared to impact with the biomechanical head models. For the latter case, the stiffness of the brain tissue influenced the predicted injury levels. The investigation of the kinematics at impact showed that a substantial portion of energy was confined within the brain during impact for the biomechanical head models. The apparent mass at impact coincided with the actual mass for the rigid dummy heads while for the human head models it was roughly the mass of the skull only.

Paper No. 07-0386-O

Rear Seat Occupant Protection In Frontal Crashes And Its Feasibility

Shashi Kuppa, *National Highway Traffic Safety Administration*
Richard Kent, Jason Foreman, Daniel P. Parent, *University of Virginia, United States*

Abstract:
As part of NHTSA's Rear Seat Occupant Protection Research Program, the Fatality Analysis Reporting System and State Data System for Florida, Pennsylvania and Maryland were utilized to estimate relative fatality rates and injury risk ratios between the front and rear seat occupants. In addition, 48 km/h frontal impact sled tests were conducted with the restrained HIII 50th percentile male dummy and cadaveric subjects in outboard rear seats. The kinematic responses and injury measures of the dummy and cadaveric subjects restrained by standard seat belts and those restrained by force limiting belts with pretensioners were examined and correlated to the observed cadaver trauma severity. The kinematic responses and the injury measures of the HIII dummy and cadaver in the rear seat were compared to those of restrained HIII dummy and cadavers in the front passenger seat in a similar sled test environment from a separate study by Kent et al (2001).

Analysis of real world data suggests that the fatality and injury risk in frontal crashes for older occupants in rear seats is significantly higher than for those in front seats (Kuppa, 2005). In addition, the relative effectiveness of rear seats with respect to front seats in frontal crashes for restrained adult occupants is reduced when the front seats are equipped with advanced restraints. The sled tests demonstrated that dummy injury measures and cadaver trauma severity are generally lower in the front seat than in the rear seat when a standard belt was used. This difference is more pronounced when a force limiting belt in the front is compared to a standard belt in the rear. The sled tests revealed that a force-limiting belt with a pretensioner in the rear seat can maintain head excursion near that occurring with a standard belt, while significantly reducing chest deformation and thoracic injury severity

Paper No. 07-0246-O

Occupant Dynamics And Injuries In Narrow-Object Side Impact

Technical Session: Biomechanics: Injury Criteria and Test Procedures

Frank Pintar, Narayan Yoganandan, Dennis J. Maiman, *Medical College of Wisconsin, United States*

Abstract:
Side impact tree/pole crashes can have devastating consequences. A series of 49 CIREN cases of narrow-object side impacts were analyzed. 26 of 49 had serious chest injury and 26 had serious head injury. Head injuries were attributed to A- or B-pillar, or roof-rail contacts in average height occupants, and were attributed to door contact for smaller-stature occupants. Of the chest injuries, 17 occupants had lung contusions and 19 had rib fractures. Of those with rib fractures, 15 of 17 had unilateral rib fractures. Examining crash test data of side pole crashes, it was evident that in tests where the pole caused intrusion at the middle of the occupant's thigh, a high degree of oblique chest loading occurred. The hypothesis was that this oblique chest loading from the door induces unilateral rib fractures, lung contusions, and possible aortic rupture. Additional testing was done in a sled laboratory to induce oblique chest loading to PMHS. A modified side impact sled buck induced oblique loading at 20 and 30 degree angles to the chest. PMHS subjects experienced unilateral rib fracture patterns. Additional dummy tests in this same configuration were also conducted. Chestband data revealed better biofidelity in the WorldSID dummy than the NHTSA-SID for oblique chest loading. These dummies however, are not currently equipped to measure oblique chest deformations. Narrow-object side impacts are realistic crash environments that can induce oblique chest loading. Because the human may be more vulnerable in this type of crash scenario, dummy biofidelity and measurements, as well as a re-examination of side injury criteria are necessary to design appropriate injury-mitigating safety devices.

Paper No. 07-0277-O

Elderly Occupant Injury: A Detailed Analysis Of Injury Patterns And Quality of Life Indicators

Catherine McCullough, Mark Scarboro, *National Highway Traffic Safety Administration*
Mark Sochor, *University of Michigan Transportation Research Center*
Ramita Sharma, *OnPoint, United States*

Abstract:
The growing population of elderly (65 years and older) Americans is expected to double by 2030. In 2005, 12 percent of the total U.S. resident population (over 36 million) were age 65 years and older. According to NHTSA, older people accounted for 15 percent of all traffic fatalities and 20 percent of all pedestrian fatalities in 2005. Approximately 191,000 older individuals were injured in traffic crashes accounting for 7 percent of all people injured in traffic crashes in 2005. These older individuals made up 15 percent of all traffic fatalities and 14 percent of all vehicle occupant fatalities. It is anticipated as the population ages, these individuals will continue to be at risk unless countermeasures are developed to mitigate these injuries.

This paper will review and compare the injury patterns from nearly 400 elderly occupants with those of their younger counterparts from CIREN. NASS analysis has shown similar trends of injury patterns and percentages. However, the detailed level of medical information and long term outcomes are not available in the NASS database. This paper will review and compare the differing body regions (head,

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neck, thorax, pelvis, etc.) to evaluate the initial outcome of injury to the elderly occupant. These will be compared to that of 16-40 year olds, 41-65 year olds, and >65 year olds. Risk of injury for the differing body regions will be calculated for all three age groups. Elderly occupant SF-36 (quality of life and physical limitations) scores will be compared with the differing age groups.

General Thrust/Point of Presentation: Identify possible trends or areas of interest related to elderly occupants sustaining serious injury in motor vehicle crashes.

Paper No. 07-0365-O

Development And Assessment Of A Surface Force Abdominal Sensor

Heiko Johannsen, Volker Schindler, *Technische Universität Berlin, Germany*

Abstract:

Abdominal injuries occur seldom but are often of high severity. Various proposals for the assessment of the abdominal injury risk have been made. Nevertheless only a few dummies are equipped with abdominal sensors.

With support from the European CHILD and APROSYS projects abdominal surface force sensors for the Hybrid III 50 percentile dummy and Q child dummies were developed. The surface matrix force sensors are able to assess the time history of the applied force and the location of the load, which is important as different abdominal regions are meant to require different load limits.

The sensors for the Q dummies were used in the CHILD project reconstruction programme. The analysis of 14 accident reconstructions indicates very good correlation between the applied load assessed by the proposed sensor and the AIS 3+ injury risk. However, the number of cases is still small. Additional reconstruction cases should be able to validate the described results.

Paper No. 07-0471-O

The Influence Of Strain Rate On The Stiffness Properties Of Human Lumbar Intervertebral Discs In Compression

Stefan Duma, Andrew Kemper, Dave McNeely, Sarah Manoogian, Craig McNally, *Virginia Tech – Wake Forest, Center for Injury Biomechanics, United States*

Abstract:

Although researchers have investigated the properties of human intervertebral discs, there has been no attempt to characterize the effects of loading rate on the stiffness of human lumbar intervertebral discs. Therefore, the purpose of this study was to develop the compressive stiffness properties of individual lumber intervertebral discs when subjected to various dynamic compressive loading rates. This was accomplished by performing a total of 44 axial compression tests on 11 individual human lumbar intervertebral discs dissected from 6 fresh frozen human cadavers, 5 male and 1 female. The adjacent vertebral bodies was fixed to a load cell with a custom aluminum pot and then subjected to dynamic

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compressive loading using a servo-hydraulic Material Testing System. Each intervertebral disc was subjected to a four part test battery in which the loading rate was increased with each test. The intervertebral disc was preconditioned to a displacement of 0.5 mm at an approximate strain rate of 0.01 s-1 for ten cycles. Each intervertebral disc was then subjected to two dynamic displacement steps, 0.5 mm and 1.0 mm, at 6.8 s-1 and 13.5 s-1 respectively. Finally, each intervertebral disc was subjected to a dynamic failure test at an approximate strain rate of 72.6 s-1. The average stiffness values for the 0.01 s-1, 6.8 s-1, 13.5 s-1, and 72.6 s-1 loading rates were 375.9 N/mm, 1835.1 N/mm, 2489.5 N/mm, and 6551.1 N/mm respectively. Since that the stiffness of lumbar intervertebral discs was shown to be highly rate dependent, a power relationship was fit to the data. The resulting relationship showed that the stiffness of lumbar intervertebral discs is proportional to the strain rate raised to the 0.29 power (R2=0.88). This relationship can be utilized in the development and validation of both mathematical and mechanical models of the human lumbar spine subjected to axial loading.

Paper No. 07-0094-O

Experimental Analysis Of Abdominal Pressure Of Pregnant Occupants During Automotive Collisions Using An AF5 Pregnant Dummy

Yasuki Motozawa, *Honda R&D Co.,Ltd./Dokkyo Medical University School of Medicine*
Masahito Hitosugi, Shogo Tokudome, *Dokkyo Medical University School of Medicine, Japan*

Abstract:
A series of sled experiments was conducted using a pregnant dummy representing the anthropometry of a pregnant woman at 30 weeks of gestation. The MAMA-2B pregnant crash test dummy, based on the Hybrid III AF5th percentile dummy developed by First Technology Safety Systems Inc. and UMTRI, was used in the experiments. Previously, the correlation between fetal outcome and the severity of injury in pregnant women in automotive collisions was addressed by the authors using data from insurance payouts in Japan. In the previous study, the prediction of negative fetal outcome was difficult using the AIS or ISS scores of the mothers, because those scores did not differ significantly between pregnant occupants with spontaneous abortions and those with healthy newborns, although the scores were significantly higher in pregnant occupants whose neonates died. Therefore, in this study, the abdominal pressure of pregnant occupants during collisions was assessed as a possible predictor of fetal outcome. Abdominal pressure during frontal and rear impact in a passenger vehicle were measured and compared. The experimental dummy seating posture was determined by measuring pregnant volunteers in an actual passenger vehicle. The results of the experiments were used to analyze the dominant factor of changes in the abdominal pressure.

Paper No. 07-0239-O

Upper Extremity Injuries In Road Traffic Accidents

Philip Wraighte, Paul Manning, Angus Wallace, *University of Nottingham*
David Hynd, *The Transport Research Laboratory, United Kingdom*

Technical Session: Biomechanics: Injury Criteria and Test Procedures

Abstract:
Research objective: Upper limb injuries in road traffic accidents have been sparsely investigated and poorly understood. The purpose of this study was to obtain more specific information on upper limb injuries sustained by front seat occupants in car accidents with a view to identifying injuries that are a priority for prevention and further research.

Methods: With ethical approval and after obtaining identification of cases from the Transport and Research Laboratory the appropriate hospital records and radiographs were reviewed. Data were analysed to identify the frequency and severity of upper limb injuries, the mechanism of injury and the impairment sustained in accordance with the American Medical Association guide. The NHS financial costs of management for the upper limb injury and that for the patient in total were calculated.

Results: Sixty two cases were reviewed (34 male), aged 18-83 years (mean 44 years). There were 20 clavicle fractures, 17 wrist and 13 forearm fractures.

The median upper limb Abbreviated Injury Score was 2 and the overall Injury Severity Score ranged from 1 to 50 (median 6). In terms of impairment, the upper extremity sensory deficit ranged from 0 to 9% and motor deficit 0 to 22.5% giving up to 5% sensory and 13.5% motor “whole person impairment”.
The mean estimated treatment cost for upper limb management was £2200 compared with a total injury treatment cost of a mean £11000 per person.

Limitations of the study include the retrospective nature and possible selection bias.

Conclusion: The study has identified the range and costs (impairment and financial) of upper limb injuries in road traffic accidents. These data will be used by researchers to both improve the current car crash dummies in the upper limb and to allow accurate finite element remodelling. Legislative changes to car requirements for upper limb safety may be brought forward in the longer term.

Paper No. 07-0317-O

Upper Extremity Injury Study: Consequences And Implications

David Hynd, Jolyon Carroll, Richard Cuerden, *TRL Ltd., United Kingdom*

Abstract:
A large-scale accident study of injuries in phases 4, 5 and 6 of the UK CCIS accident database showed that upper extremity injuries were increasing in frequency in frontal impacts, particularly when an airbag deployed. However, it was difficult to identify injury mechanisms and costs from the information in the database. Therefore, an in-depth case-by-case study of upper extremity injuries has been undertaken to determine the mechanisms, costs and long term consequences (disability or impairment) of the injuries, in order to set priorities for injury prevention. The study has been undertaken in three phases:

- A retrospective study of medical notes (from 75 car accident cases), giving more detail on the specific upper extremity injuries and the mechanisms that could have caused them.

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- A prospective study of patients recruited at an Emergency Department (25 cases), with a follow-up of up to six months to assess longer-term consequences of the injury.
- A review of physiotherapy treatment case notes (288 cases), looking at cases that may not have been assessed at a hospital Emergency Department.

Four hospitals and three physiotherapy practices were recruited to this study. Evaluations of short and long-term costs and residual impairment resulting from these injuries have been made. The long term costs were assessed through surgical costs, cost of other treatment and time off work, whilst impairment was assessed qualitatively by range of motion, pain and functional impairments and quantitatively using the American Medical Association Guides.

A potential limitation of the study is how representative the three samples are of the UK population.

This study offers a unique insight into the mechanisms causing and long-term consequences arising from specific upper extremity injuries. From this, priorities for injury prevention are presented.

Paper No. 07-0345-O

Characterization Of Knee Impacts In Frontal Crashes

Jonathan Rupp, Carl Miller, Nathaniel Madura, Matthew Reed, Nichole L. Ritchie, *University of Michigan Transportation Research Institute*

Lawrence Schneider, *University of Michigan Transportation Research Institute and Department of Biomedical Engineering, United States*

Abstract:
Results of previous research have suggested that the tolerance of knee during loading to the anterior surface in frontal crashes varies with knee angle and the orientation and stiffness of the surface loading the knee. Prior to quantifying the effects of these parameters on knee tolerance using biomechanical testing, it is important to characterize the variability in these parameters in frontal crashes. This paper reports on a study that characterized the distributions of knee angles, thigh-to-knee-bolster angles, and contacted surfaces for drivers in frontal crashes. Knee-impact surfaces and the injuries produced by different contacts were based on analysis of CIREN frontal crashes. Femur force histories from unbelted FMVSS 208 and NCAP tests were analyzed to estimate the ranges of peak forces and knee loading rates produced by knee-bolster contacts in frontal crash. Cadaver knee impacts into production knee bolsters were used to estimate the contact area and distribution of force across the patella and femoral condyles. Analyses of the seating locations and driving postures of 36 vehicle occupants varying in stature from small female to large male in three vehicle packages were used to estimate knee angles and thigh-to-knee-bolster angles at the time of knee-bolster contact. Results of these analyses provide insight on the ranges of test parameters that should be used to explore the effects of the knee angle, bolster angle, and bolster stiffness on knee tolerance in real-world frontal motor-vehicle crashes.

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Paper No. 07-0470-O

The Material Properties Of Human Tibia Cortical Bone In Tension And Compression: Effects Of Strain Rate And Orientation

Stefan Duma, Andrew Kemper, Eric Kennedy, Sarah Manoogian, Craig McNally, *Virginia Tech – Wake Forest, Center for Injury Biomechanics, United States*

Abstract:

The risk of sustaining tibia fractures as a result of a frontal crash is commonly assessed by applying measurements taken from anthropometric test devices to the tibia index. The tibia index is based on the tensile and compressive failure stresses of tibia compact bone, and addresses combined axial compression and bending. However, the failure properties of human tibia compact bone have only been determined under static loading. Therefore, the purpose of this study was to develop the tensile and compressive material properties for human tibia cortical bone coupons when subjected to three loading rates and two specimen orientations. This study presents 104 machined cortical bone coupon tests from 12 loading configurations using four male fresh frozen human tibias. A servo-hydraulic Material Testing System (MTS) was used to apply tension and compression loads to failure at approximately 0.05 s-1, 0.5 s-1, and 5.0 s-1 on lateral and axial cortical bone coupons. The average failure stress for the static, quasi-static, and dynamic tests were 150.6 MPa, 159.8 MPa, and 192.3 MPa for axial tension specimens and 177.2 MPa, 208.9 MPa, and 214.1 MPa for axial compression specimens. Although the results showed that the average failure stress increased with increasing loading rate for axial tension, axial compression, and lateral compression test groups, the differences were not found to be significant. Although minor, both axial and lateral tension specimens showed a decrease in the failure strain and an increase the modulus with increasing strain rate. There were no significant trends found for either axial or lateral compression samples, with respect to the modulus or failure strain. The modulus, failure strain, and failure stress were significantly larger for axial tension specimens versus lateral specimens ($p<0.05$). For compression specimens, the modulus and failure stress were significantly larger for axial versus lateral specimens ($p<0.05$).

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Technical Session: Motorcycle Safety

Oral Presentations | Thursday, June 21, 2007 | 9:00a.m.-12:00p.m.

Chairperson: Claudio Lomonaco, Italy | Track A | Room: Salle Rhône 3
Co-Chairperson: Younghan Youn, Republic Of Korea

Paper No. 07-0080-O
SIM Project: A Way To PTW Integrated Safety
Federico Galliano, Mario Donato Santucci, *Piaggio & C SpA,*
Massimo Guiggiani, University of Pisa - Department of Mechanical, Nuclear and Production Engineering, Italy
Oliver Hoffmann, *Continental Teves AG&Co. oHG, Germany*
Begoña Pérez-Magallón, *CIDAUT, Spain*

Abstract:
The paper will describe the features and characteristics of the project SIM (Safety In Motion). SIM Project is aimed at carrying out R&D activities addressing in-depth studies of a suitable and comprehensive safety strategy for powered-two-wheel (PTW) vehicles, in order to avoid road accidents and/or mitigate their consequences. Main objectives of SIM are:

- to identify a suitable safety strategy for PTWs;
- to enhance preventive and active safety acting on electronic vehicle management and improving Human-Machine-Interaction (HMI);
- to focus on integral passive safety devices;

An integrated approach to the complex concept of motorcycle safety would establish a matrix relationship between the three main factors or pillars for safety (PTW, rider and infrastructure) and the different aspects related to accident dynamics, from before-precipitating event to crash event (dealing with preventive, active and passive safety). According to that, SIM project focuses on the vehicle safety aspects, including the human-machine-interaction.
Main results expected are:

- development of electronic active devices (e.g. enhanced anti-lock braking system, traction control and brake-by-wire) for powered two-wheelers;
- development of a passive safety algorithm to activate passive safety devices;
- adaptation of protective inflatable devices located on the rider (garment) and on the vehicle (for lower limbs protection);
- implementation of innovative HMI

On-road and laboratory tests, based on the most relevant accident scenarios, will be conducted in order to evaluate the effectiveness of the safety system devices (e.g. mitigation of injuries via inflatable devices, probability of avoiding accident, etc…) fitted on an integrated concept vehicle.
Innovation aspects are mainly an integrated approach to the issue and the introduction of new safety technologies in PTW field.

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Paper No. 07-0095-O

Basic Research For A New Airbag System For Motorcycle

Motoaki Deguchi, Shoji Kanbe, Yousei Hannya, *Yamaha Motor Co.,Ltd., Japan*

Abstract:

The computer simulation on motorcycle crashworthiness has been introduced to develop and evaluate a new airbag system for motorcycle. We chose MADYMO (multi-body dynamics) and PAM-SAFE (finite element method) for the basic simulation software. In addition to using these computer simulation tools, several full-scale tests were performed. This new airbag system has some features that are newly developed for motorcycle. This system has been shown to be hopeful by some simulations and tests. However there are still many technical issues to be investigated and solved in order to put the system in practical use.

Paper No. 07-0182-O

LONG Lighting System For Enhanced Conspicuity Of Motorcycles

Yojiro Tsutsumi, Kazuyuki Maruyama, *Honda R&D, Japan*

Abstract:

LONG (Longitudinal Oriented Normative time Gap compensate) lighting system that enhances the conspicuity of motorcycles in both sense of distance and speed is proposed. Cognitive psychology is applied to the system. It is considered that motorcycles at the same distance and speed as automobiles may be perceived longer distance and lower speed than the automobiles, because of their higher lights location and narrower lights layout compared with automobiles. So lights of the system are located in lower and wider area. If the distance between a subject and the horizon location in a visual field becomes longer, the subject is perceived as nearer. This effect is a kind of “perspective”. Using the effect, lights are located in the low position in order to enhance a sense of distance. On the other hand, if visual size of the subject is large, the expanding amount of the image on the retina of the observer will increase then the accuracy of speed perception goes up. Using this effect, lights are also located in the high position in order to enhance a sense of speed. The system is evaluated by measuring critical time gap in right turn across path scenario. If a vehicle approaches more from the opposite direction, a driver gives up right-turn at a crossing. The passage time from the moment to give up until the vehicle pass the driver’s side is called critical time gap in right turn across path scenario. It is shown that motorcycles with the system have the same conspicuity as automobiles by measuring critical time gaps of about 20 experimental subjects. Lights layout dependence and luminous intensity dependence are also reported.

Paper No. 07-0232-O

Injuries Among Motorised Two-Wheelers In Relation To Vehicle And Crash Characteristics In Rhone, France

Aurelie Moskal, Jean-Louis Martin, Bernard Laumon, Erik Lenguerrand, *French Research Institute on Transport and Safety, France*

Technical Session: Motorcycle Safety

Abstract:
Objective: This study described injuries according to vehicle and crash characteristics in a group of motorised two-wheelers receiving medical care after a crash in the Rhone County in France.

Methods and data sources: We explored all motorised two-wheelers injured in a road crash between 1996 and 2003 recorded by the road trauma registry in the Rhone County in France. The data collected for each casualty were gender, age, date, time of the crash, crash location, road user type and injury assessment. Injury diagnoses were coded according to the Abbreviated Injury Scale (1990). The registry data were linked at the casualty level to French police data for the Rhone County. Police crash reports provided more precise information on crash type, crash location, place on the vehicle, vehicle type (motorcycle, moped), collision type and helmet use.

Expected results: We described vehicle and crash characteristics of 4 thousands injured riders reported by the trauma registry and the police. We reported the frequency, nature, severity and injury pattern of motorised two wheelers according to vehicle and crash characteristics.

Discussion : Few studies include information from both medical and police sources, and no such results have been reported for motorised two-wheelers. We expect this study to provide more information on the anatomic regions frequently and seriously injured with regard to crash type and collision type. We aim to propose recommendations for rider protection like safety equipment and modifications in motorcycle design.

Limitation of study: Some bias may appear in the Record linkage procedure between the two data sources which we are able to estimate. It wasn't possible with our data to take into account speed effect on injury severity.

Paper No. 07-0250-O

Study On Improving Two-Wheeled Vehicle Conspicuity

Masanori Motoki, Hiroshi Hashimoto, Masahiro Noguchi, Tamotsu Hirao, *Japan Automobile Research Institute*
Susumu Takahashi, Makoto Ishiwatari, *Japan Automobile Manufacturers Association, Japan*

Abstract:
This study was conducted to clarify the effects of two-wheeled vehicles' AHO (automatic headlamp on) and position lamps on improving their conspicuity during daytime and sunrise/sunset hours. Two research items as follows were conducted.
(1) Effect of AHO on reducing injury-causing accidents
Traffic accident data involving two-wheeled vehicle from 1990 to 2001 in Japan were used. Specific accident configurations closely associated with the conspicuity of two-wheeled vehicles (collision while turning right, right-angle collision, head-on collision) were selected and analyzed. The findings are as follows.

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AHO was confirmed to be effective in reducing the number of the specific accidents closely associated with the conspicuity of two-wheeled vehicles during daytime and sunrise/sunset hours.

As the percentage of AHO-equipped vehicles in the two-wheeled vehicle fleet rose from zero of 1990 to 71 percent of 2001, it could be calculated that AHO's reduction of specific accidents amounted to 12,124 cases (16.0%) during daytime and sunrise/sunset hours.

(2) Effect of AHO and position lamps on improving the conspicuity of two-wheeled vehicles

Twelve lamp experts were employed as subjects. The subjects observed an oncoming motorcycle approaching followed by a passenger car with passing beams on 30m behind, and instructed to indicate the motorcycle conspicuity when the motorcycle arrived at a point of 100m ahead of their eye-points. Seven lighting conditions of the motorcycle were observed. The findings are as follows.

AHO have a conspicuity enhancing effect on two-wheeled vehicles during daytime and sunrise/sunset hours.

To further improve the conspicuity of two-wheeled vehicles, it is effective to combine amber position lamps with AHO. The effect of position lamps can be increased by optimizing their color, luminous intensity and distance from the headlamp.

Paper No. 07-0270-O

MARVin - Model For Assessing Risks Of Road Infrastructure

Michael Aleksa, Peter Maurer, Peter Saleh, Rainer Stütz, *Arsenal Research, Austria*

Abstract:

The project MARVin is about assessing the relation between road infrastructure and road accidents. A large amount of data about the Austrian roads was gathered with the RoadSTAR (Road Surface Tester of arsenal research). This data was put into a database associated with accident data. The result was a database of about 12.500 km of road where all the road parameters (skid resistance, cross fall, gradient, texture, roughness, curve radius, etc.) belonging to a certain accident can be retrieved.

One approach is to take a piece of road where accidents happened and to find a very similar piece of road with roughly the same parameters. These pieces of roads can be an interesting lead to reduce the number of accidents caused by road conditions. It could be the case that on a certain piece of road a lot of accidents happened while on another piece, very similar in road parameters, no accidents happened at all. In this case there can be other parameters (that are not in the database) that influence the road safety such as speed limits or traffic density etc.

MARVin is also planned as an open platform to integrate more relevant data like traffic flow data or weather data.

MARVin is a new tool for crash-causes-research, to identify “virtual” road sections with a high crash risk potential or “virtual” hot spots. It is possible to realize route graphs which show all kinds of infrastructure parameters and located accident events. This is a practical tool to audit existing roads as well as planned roads and to develop accident preventive measures in terms of road constructions and road infrastructure.

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Regarding to the accident risk of powered-two-wheelers (PTWs) the tendency of a significant influence of the road construction and the quality of the road surface on motorcycle accidents, can be shown in the first results of pilot studies and analysis.

Paper No. 07-0287-O

Use of Geocoded FARS Data To Analyze Fatal Motorcycle Crash Trends

Kevin Majka, Alan Blatt, Marie Flanigan, *Calspan-University at Buffalo Research Center*
Saverio Pugliese, *Calspan, United States*

Abstract:
Much work has been done recently to examine the trends, contributing factors and characteristics of the increasing number of fatal motorcycle crashes occurring in the United States. This paper explores two new resources, geocoded FARS data and roadway orthoimagery, to examine the geo-spatial characteristics of U.S. fatal motorcycle crashes. The objective of this study is to investigate the geospatial patterns of fatal motorcycle crashes to determine if newly available analysis tools can be used to gain additional insight in crash causation and potential crash mitigation strategies.

Using 2001, 2002, 2003, and 2004 FARS crash data (that were previously geocoded by NHTSA's National Center for Statistics and Analysis), we have characterized the locations in the United States that have had fatal motorcycle crashes. Locations where multiple crashes occurred were identified by using spatial and attribute queries of the NHTSA FARS database after the database was imported into a Geographic Information System. During the period of 2001 through 2004 FARS identifies 14,189 motorcycle rider fatalities. Approximately 92 percent of these fatalities (13,019) were successfully geocoded and entered into the analyses. A majority (about 70%) of motorcycle fatalities occur on undivided roadways.

The analysis results will identify the roadway types and associated features where multiple fatal crashes have occurred during the period 2001-2004. A new valuable approach to the analysis of fatal motorcycle crashes will be described. High resolution orthoimagery is not available for all roadways. In addition, care must be taken to insure that available imagery displays roadway features at the time of the crash.

This paper provides the first geospatial analysis of fatal U.S. motorcycle crashes using geocoded FARS data and available roadway orthoimagery. Precise crash location, roadway imagery and FARS crash attributes provide unique opportunities to investigate crash trends, causation factors and potential crash mitigation techniques.

Paper No. 07-0301-O

Intelligent Transport Systems And Motorcycle Safety

Megan Bayly, Michael Regan, Simon Hosking, *Monash University Accident Research Centre, Australia*

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Abstract:
In comparison to the widespread advancement of safety-enhancing technologies for passenger vehicles, there has been only limited development of Intelligent Transport Systems (ITS) for motorcycles. Considering the international over-representation of motorcyclists in crash statistics, in particular, the high incidence of loss of control crashes, multiple-vehicle crashes and conspicuity related crashes, it would appear that the development of ITS for motorcycles should be given greater priority. The current study aimed to investigate the extent to which ITS have been applied to motorcycles (including both existing and emerging technologies) and prioritise these ITS according to their likely safety benefits to motorcycle safety. A review of the ITS literature was conducted, followed by consultations with ITS and motorcycle safety experts. This process confirmed that very few motorcycle-specific ITS currently exist, although there is the potential to adapt emerging and existing ITS for other vehicles to motorcycles. These ITS technologies were tabulated and prioritised according to their potential to enhance the safety of motorcyclists. Technologies that were seen to enhance the stability and braking power of motorcycles were assigned highest priority in this list, as these are most likely to be relevant to almost all motorcycle crash types, particularly loss of control crashes. While such technologies have the potential to address vital safety issues for motorcyclists, the acceptability and feasibility of specific ITS technologies for motorcycles should also be evaluated. The need for research and development of these high priority ITS for motorcyclists is discussed in relation to these issues.

Paper No. 07-0312-O

The Motorcycle Integral Brake System MIB - The Advanced Brake Solution For High Performance Motorcycles

Alfred Eckert Oliver Hoffmann, James Remfrey, Jürgen Woywod, *Continental Automotive Systems, Germany*

Abstract:
Brake systems for motorcycles are widespread with differing technical solutions. Starting with a conventional brake system with two independent circuits, an Antilock Brake System (ABS) can be added to improve safety and stability. Building up a hydraulic connection between the front brake and the rear brake or vice versa, a combined brake system can be realized in order to enhance safety and comfort. These systems are fixed in their functions and dimensions and it takes considerable effort to implement changes. This low flexibility makes it nearly impossible to bring in additional functions or in building up corresponding brake pressure in dependence of varying driving situations.
With the Motorcycle Integral Brake system (MIB), which will be introduced 2006 into the market, motorcycle manufacturers have the possibility to realize any combined integral functionality characteristic. In addition to that, the pressure in each brake circuit can be build-up actively so that nearly any reaction of the system to any driving situation is possible. In addition, integral brake functions can be adapted to the philosophy of the motorcycle manufacturer as well as numerous additional functions which were impossible until now.
This paper describes the Motorcycle Integral Brake system, its system layout compared with other brake systems and its different hydraulical and functional capabilities.

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Paper No. 07-0332-O

Technical Bases For The Development Of A Test Standard For Impacts Of Powered Two-Wheelers On Roadside Barriers

Steffen Peldschus, Erich Schuller, *Ludwig-Maximilian University*
Jens Koenig, Marcus Gaertner, *DEKRA Automobil GmbH*
David Garcia Ruiz, *CIDAUT*
Alberto Mansilla, *Universidad de Valladolid, Spain*

Abstract:
The problem of injuries to motorcyclists caused by impacts on roadside barriers has numerously been pointed out in the literature. Nevertheless, there is a lack of agreement concerning injury criteria for these particular cases. One of the objectives of the European research project APROSYS SP4 "Motorcycle Accidents" is to propose a European crash test standard for the assessment of impact performance of roadside barriers with respect to injury risks. This paper describes the methodology of work that has been followed for the proposal of the standard.
In-depth databases have been analysed in order to evaluate the nature of motorcyclists' impacts to barriers and to gain knowledge in addition to the anecdotal cases reported in the literature. About 1000 accidents of powered two-wheelers from four different databases were analysed. In contrast to previous views, impacts in upright riding position seem to occur equally often as impacts in sliding position. A detailed analysis of the current testing procedures (e.g. the Spanish standard, the procedure developed by INRETS, France) has been performed. Full-scale crash tests in sliding position, performed by CIDAUT, and upright position, performed by DEKRA, were included in this analysis. The selection of the injury criteria, especially in head, neck and thorax, has to take into consideration the peculiarities of this kind of accidents. It was concluded that the biofidelity of available dummies (Hybrid III) needs to be further assessed for this particular application, e.g. by comparative simulations using HUMOS2 model.
The knowledge gained at the light of the results obtained from the described methodology will be used in the future development of a standard.

Paper No. 07-0342-O

Real Cases Motorcycle And Rider Race Data Investigation: Fall Behavior Analysis

Andrea Aguggiaro, Vittore Cossalter, *Università di Padova*
Andrea Ambrogi, Alessandro Bellati, *DAINESE, S.p.A., Italy*
Dirk Debus, *2D-Datarecording GmbH, Germany*

Abstract:
The need for safety is being perceived also in the motorcycle race context, and the research for more protective motorcycle garments is becoming more challenging. In this scenario, DAINESE is working to investigate for new solutions to improve rider safety together with some racing teams.
In our work dynamical measurements of several motorcycle crashes, recorded both on the rider and the motorcycle, are presented and analyzed investigating repeatability and general tendencies among the different cases.

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The available data were collected during the 2006 MotoGp World Championship, which proven to be a perfect scenario to acquire motorcycles limit-condition-driving data and a challenging environment for testing innovative safety devices.
Although focused on the race competitions, this study should also be useful to develop more general purposes protection systems for riders in the future.

Paper No. 07-0370-O

Opportunities For Safety Improvements In Motorcycle Crashes In The United States

Randa Radwan Samaha, Kazuyoshi Kuroki, Kennerly H. Digges, *George Washington University*
James V. Ouellet, *Motorcycle Accident Analysis, United States*

Abstract:
This paper investigates motorcycle crashes in the United States in light of the steady growth of the crash problem since the late nineties. The goals of the research are to explore factors contributing to crash causation and to determine opportunities of improving safety for motorcycle riders on U. S. Roads. Motorcyclist fatalities have more than doubled since 1997. In 2005, 4553 motorcycle riders died in crashes on U.S. roads, accounting for 10.5% of all traffic fatalities as compared with 5.3% of traffic fatalities in 1997. Moreover, motorcycle fatality rates per 100,000 registered vehicles increased from a low of 50 in 1997 to 70 in 2004. When compared to passengers (15 rate), motorcycles rider were 4.6 times more likely to be killed in motor vehicle traffic crash in 2004.
In this paper, a nationally representative analysis was performed using the 1992-2004 National Automotive Sampling System/General Estimate System (NASS/GES) data files. The study population includes all crashes involving at least one motorcycle and considers both motorcycle drivers and riders. The analyses focused on crash configuration, rider injury severity, age groupings, pre-crash actions, alcohol involvement, speed relation, and vision obstruction; motorcycle engine size and vehicle contributing factors; roadway relation to junction, surface condition, speed limit, and light condition. Data trends pre and post 1998 are presented. An examination of motorcycles crashes, fatalities, and injuries that could be addressed by existing and future categories of countermeasures, based on crash configuration and other crash characteristics, is also presented. Estimates of the magnitude of the opportunities, in terms of the size of the present injured populations to which the countermeasure is relevant, are also examined. Countermeasure categories in both motorcycle crash avoidance and crash protection are considered.

Paper No. 07-0474-O

The Risk Of Fatality In Motorcycle Crashes With Roadside Barriers

Hampton Gabler, *Virginia Tech, United States*

Abstract:
Research Question: Because motorcycles comprise only 2% of registered U.S. vehicles, guardrails are not designed to safely interact with motorcycles in collisions. What is the risk of fatality in motorcycle impacts with guardrail? Are motorcyclists overrepresented in fatal crashes with guardrail?

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Methods: This study was based on examination of the Fatality Analysis Reporting System (FARS) database and the National Automotive Sampling System (NASS) General Sampling System (GES). FARS was used to determine the number of guardrail-related fatalities. GES was used to determine the number of impacts with guardrail regardless of injury outcome. Fatality risk was computed as the number of fatalities per guardrail impact.

Results: The distribution of fatalities and fatality risk are computed by vehicle type. In 2004, motorcyclists were found to be second only to car occupants in total number of guardrail crash fatalities. This is surprising as cars compose over half of the vehicle fleet (56%) while motorcycles comprise only 2% of the registered vehicles. Approximately, one in ten motorcyclists striking a guardrail will be fatally injured – a fatality risk nearly 100 times higher than for car occupants involved in a collision with a guardrail. Nearly two-thirds of all fatally-injured motorcyclists involved in a guardrail crash were wearing their helmets.

Conclusions: Motorcyclists are overrepresented in fatal crashes with guardrail. At the current growth rate of the motorcycle fleet, motorcyclists are posed to become the leading victim of fatal injury in collisions with guardrails in 2005.

Limitation Of Study: FARS Does Not Allow Adjustment For Potential Confounding Factors, E.G. impact speed.
What does this paper offer that is new in the field? This is the first paper of its kind to analyze the fatality risk of motorcycle impacts with guardrail using FARS and GES.

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Technical Session: Advances in Child Occupant Protection/Restraint Systems

Oral Presentations | Thursday, June 21, 2007 | 9:00a.m.-12:00p.m.

Chairperson: Craig Newland, Australia | Track B |
Room: Auditorium Lumière
Co-Chairperson: Hideki Yonezawa, Japan

Paper No. 07-0216-O
The Effect Of Restraint Use And Crash Mode On Injury Severity Risk For Children Santokh Singh, Linda McCray, *National Highway Traffic Safety Administration*
John Brewer, *Volpe National Transportation Systems Center, United States*

Abstract:
The safety of children in motor vehicle crashes is a major concern. Although child restraint systems (CRS) are mandated for their protection, children are still exposed to the risk of injuries ranging from minor to fatal. This study is focused on identification of the scenarios under which CRS is less effective and hence need attention of the researchers, manufacturers, and legislators. Some data concerns are also raised in course of the study. The scenarios composed of some possible contributors: restraint use, impact type, injury severity, and age group of crash involved children are investigated at rather a micro level to estimate the associated relative risks. Specifically, children of age groups: infants, 1 to 3, 4 to 8, and 9 to 12 year olds, who were either uninjured, or sustained minor to fatal injuries in frontal, side, rear-end, or rollover crashes, formed the study population.

The analysis dataset is extracted from the National Automotive Sampling System– Crashworthiness Data System. The study population is segmented based on three injury risk factors: Age group, Restraint use and Impact crash mode. An information measure is employed to identify clusters in which the quantity data is limited or contains insufficient ‘information’, thereby suggesting the importance of collecting more data in certain segments of the population. Injury risk factors may have an individual as well as joint influence on the outcome (injury severity) of a crash. The significance of the overall association between these factors is tested by the contingency analysis. This, however, provides only a broad picture of the phenomenon. Configural frequency analysis is employed to identify the factor-based clusters that range from strong to complete absence of factor association. The estimates of the relative risks associated with different clusters are obtained to infer, for example, in which crash types are child restraints least effective.

Paper No. 07-0464-O
Protection For The Smallest Occupant – Status Quo And Potentials Concerning The Development Of Child Restraint Systems
Sebastian Weber, Heiko Johannsen, Volker Schindler, *Technische Universität Berlin*
Britta Schnottale, *Bundesanstalt für Straßenwesen, Germany*

Technical Session: Advances in Child Occupant Protection/Restraint Systems

Abstract:
The use of proper CRS is mandatory for children travelling in cars. The analysis of the quantity of restrained children shows that more than 90% of the children in Germany are protected. Looking at the quality of the protection, a big discrepancy between restrained and well protected children can be seen. Two of three children in Germany are not properly protected. For that reason investigations and optimisations on two different topics are necessary: The technical improvement of CRS and the ease of use of CRS.

The project "Optimisation of CRS" is funded by BASt and will be finalised by beginning of 2007. Detailed investigations at the crash facility of TU Berlin showed the differences between good and poor CRS. The use of Q-dummies for these crash tests allowed the assessment of a variety of dummy readings. However, for a complete assessment of the protection level of child restraints the interpretation of dummy readings and dummy kinematics from high speed video analysis is necessary. The variation between different types of CRS is partially high.

Consideration of the knowledge gained by the comparison of different CRS in crash tests would lead to some improvements of the CRS. But improvement of child safety is not only a technical issue. People should use CRS in the correct way. Misuse and incorrect handling could lead to less security than correct usage of a poor CRS. For that reason new technical issues are necessary to improve the child safety AND the ease of use. Only the combination of both parts can significantly increase the child safety. The presentation will give a status quo of today's CRS market and will show new ideas – with technical and psychological background.

This paper will present
- • Summary of statistical accident information concerning children in cars and case studies
- • Comparison of different CRS using different test procedures
- • Proposals for the improved child safety
  - Technical issue
  - Usability

Paper No. 07-0461-O

Spinal Injuries In Rear Seated Child Occupants Aged 8 – 16 Years

Julie Brown, Lynne Bilston, *Prince of Wales Medical Research Institute, Australia*

Abstract:
While spinal injury in child occupants is relatively rare, the significance of these injuries is high. For children too big for booster seats the best available protection is the adult seat belt in the rear seat. This paper presents a case series of 25 rear seated restrained child occupants aged between 8 and 16 years diagnosed with a injury to the spinal region, and discusses the current lack of regulatory or consumer assessment of injury risk to child occupants too big for booster seats.

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Data was collected from retrospective medical record review of all children treated at two major children's hospitals over a five year period. Cases were collected using spinal trauma related ICD 10 codes and all restrained child occupants between the ages of 8 and 16 years (inclusive) were extracted. All types and severities of spinal injuries were included. Restraint, seating position and crash details were taken from ambulance reports.

Most children sustained minor injuries (56%), however 11 of the 25 sustained moderate to severe spinal injuries. These include spinal cord injuries, vertebral fractures and dislocations and major ligamentous damage. Most minor injury occurred in the cervical region, and most serious injury occurred in the lumbar region. Almost all children were using the available lap sash seat belt (22/25).

There was more serious spinal injury among those children aged 8 – 12 (10/13) than there was among the older children aged 13-16 (3/12), and more than half of the younger children (8 of 13) had associated abdominal injuries.

A review of international booster seat use legislation, and regulatory and consumer assessment of injury potential to older rear seated children is also presented. The need for more widespread evaluation of rear safety for older child occupants is discussed.

Paper No. 07-0441-O

Abdominal Injury Risk For Children Seated In Belt Positioning Booster Seats

Jessica Steps Jermakian, *Children's Hospital of Philadelphia*
Michael J. Kallan, *University of Pennsylvania*
Kristy B. Arbogast, *Children's Hospital of Philadelphia, University of Pennsylvania, United States*

Abstract:
Previous studies have demonstrated that booster seats reduce the risk of seat belt syndrome, in particular the occurrence of abdominal organ injuries, by improving the fit of the seat belt on young children and encouraging better posture and compatibility with the vehicle seat itself. However, European data has shown that abdominal injuries are still prevalent even with the use of booster seats. In the US, as booster seat use increases and more data become available, particularly on older children in booster seats, the abdominal injury risk to these children should be revisited. Therefore the objective of this study is to quantify the time trend increase in booster seat use for rear row(s) seated children age 4 to 7 years old and define the prevalence of abdominal injuries restrained by belt-positioning booster seats. A probability sample of 4,953 crashes involving 5,820 children, weighted to represent 97,566 children in 83,326 crashes was collected from an on-going child specific crash surveillance system between December 1, 1998, and December 31, 2005. Appropriate restraint, including the use of belt positioning boosters, increased from 17% to 64% among 4 to 7 year olds during the time period of data collection. Abdominal injuries occurred among 0.17% of all 4- to 7-year-olds, including 0.21% of those in seat belts and 0.07% of those in belt-positioning booster seats. Among children restrained in belt positioning

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booster seats, 6 and 7 year olds had no higher risk of abdominal injuries than 4 and 5 year olds. This study points to a reduced abdominal injury risk for children in belt-positioning booster seats although abdominal injuries still occurred in some booster-seated children, suggesting the need for further in-depth study into the circumstances surrounding these injuries.

Paper No. 07-0220-O

The Feasibility Of Age-Based Criteria For Child Restraint Selection

Robert Anderson, T.P. Hutchinson, *University of Adelaide, Australia*

Abstract:
Correct child restraint use is important for child occupant safety. Surveys in various countries have repeatedly shown that many parents do not select the correct type of restraint for their children and lack knowledge about correct restraint selection. Advice, and increasingly regulation, is based on the dimensions of the child, usually height and weight, but such prescriptions may be difficult for parents to remember, and parents often do not know the weight of their children. The child's age might be preferable for promotion and regulation because parents know it and it is simple. What is not properly recognised is that definite, non-overlapping age ranges would imply (using anthropometric survey data) design specifications for each kind of seat. Hence age criteria could be used to advise parents and regulate the design of the seat. This paper presents a methodology for determining seat design parameters when the overarching aim is that the seat should accommodate children of a certain age range. Using human growth data, we demonstrate how seat requirements can be determined for a predefined age transition, such that the tradeoff between children too large for the smaller seat and the number to small for the larger seat can be estimated and optimised for a given transition age. The tradeoff estimate is closely related to concepts of sensitivity and specificity. The consequences of age-based seat transitions for children in the regulatory jurisdictions of Australia, Europe and the North America are presented. The analysis shows that in Australia, where there are currently significant overlaps in the weight ranges of each type of restraint, recommendations to make restraint transitions at 6 months and 4 years of age would mean that about 5% of all children under the age of six would be in a restraint unsuited to their mass.

Paper No. 07-0298-O

Investigation Of Lower Anchorage Systems For Child Restraints In Australia

Thomas Belcher, Craig Newland, *Australian Government Department of Transport and Regional Services, Australia*

Abstract:
Australia is considering allowing the use of lower anchorage systems for child restraints in motor vehicles, however, care needs to be taken to ensure that the mix of existing Australian child restraint systems and any proposed lower anchorage system does not pose safety risks for children. In addition, it is desirable

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to avoid unique requirements for an Australian lower anchorage system and hence an assessment of UNECE ISOFIX and US FMVSS LATCH requirements was undertaken.
A series of 28 frontal impact sled tests were conducted based on the Australian Standard AS/NZS 3629 child restraint dynamic test method. A further series of 15 tests were conducted in a vehicle body mounted on an impact sled with an acceleration-time history representative of a 56 km/h full frontal rigid barrier crash. Three different models of forward-facing child restraint were tested, with varying anchorage configurations including rigid ISOFIX, flexible LATCH strap and 3-point seatbelt. Top tethers were evaluated with anchorages directly behind the child restraint (0°) and offset at an angle of 20°. P3 and Hybrid III 3 year old dummies were used. Anchorage loads and safety performance of the restraint system were assessed. In tests in the vehicle body, maximum dynamic top tether loads were in the range of 7-8 kN and maximum dynamic lower anchorage loads are estimated to be in the range 13-14 kN. Tests using rigid ISOFIX anchorages generally produced lower head acceleration and forward excursion than other tested anchorage types, however, this was accompanied by increased chest deflections and neck flexion moments. These data suggest that lower anchorage systems may be acceptable in Australia, but that modifications to the UNECE and LATCH requirements may be required to ensure compatibility with existing Australian child restraint systems without a degradation of child safety.

Paper No. 07-0268-O

Rear Seat Frontal Impact Protection Using An Attitude, Handling And Safety Approach

Katarina Bohman, Ola Boström, *Autoliv Research*
Anna-Lisa Osvalder, Maria Eriksson, *Chalmers University, Sweden*

Abstract:

Real life data have shown that booster cushions are highly beneficial to belted children. Still, misuse and non-use problems remain. Also, the belt system in the rear seat may be optimized both for children and adults.
The aim of this study was to evaluate techniques offering benefits, in an attitude, handling and safety perspective, for children seated in booster cushions and adults.
Three methods were used. Focus groups with 18 children of 7 years discussed the use of booster cushions. Secondly, in a handling study 7 children and their parents were observed when buckling up in a car using an integrated booster cushion and an aftermarket booster cushion. Finally, sled tests were performed with HIII 6y and HIII 50th dummies. Different booster cushions and seat belt systems were used, including retractors with belt load-adaptivity (different levels for adults and children) and pretensioning
It was found that children want to use the booster cushions due to safety and comfort reasons, but at the same time they perceive the use of booster cushion as childish. Parents motivated non-use by inconvenience.
The handling study showed that adults felt secure when handling the integrated booster cushion since it could only be unfolded in one way. The integration facilitated the buckling up. Also, it was stable when enter/leaving the car. Misuse was detected for 5 children and for 1 adult when using the after market booster cushion, while there was no misuse with the integrated version.

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The sled tests with the retractors with belt load-adaptivity and pretensioning resulted in optimal head, neck and chest loading as well as forward displacement.
To conclude, combinations of techniques such as integrated booster cushions, belt pretensioning and load-adaptivity may increase (correct) usage of restraints, decrease dummy injury values and keep forward displacements thereby saving rear seat occupant lives.

Paper No. 07-0322-O

Rear Seat Safety For The Growing Child; A New 2-Stage Integrated Booster Cushion

Lotta Jakobsson, Henrik Wiberg, Jorgen Gustafsson, Irene Isaksson-Hellman, *Volvo Cars, Sweden*

Abstract:
The overall protection of the growing child in the car is a question of designing child safety systems specifically for the needs of the child, such as age, stature and weight. Safety benefits are seen if children use booster cushions up to 12 years of age. The aim of the present study is to evaluate the safety potential of a new rear seat design for the growing child, including 2-stage booster cushions together with progressive load-limiters.
The 2-stage booster cushion is an evolution of the first generation integrated booster cushions introduced 1990. The 2-stage booster cushion was designed to help an even better fit to more sizes of forward facing children. In its high position, the seat belt fit for the smaller children is in focus. In its low position it offers a more adapted thigh support (reducing likelihood of slouching) for the larger children, as compared to when using the adult position. The progressive load-limiter is adapted for the child.
Seat belt fit study of different child sizes as well as crash test results using different child dummy sizes are presented in the paper. Referring to accident data of 2500 children in prior Volvo rear seats, the safety potential is evaluated.
The study presents a new rear seat safety concept for enhanced overall protection for children aged 4-12. The 2-stage booster cushion and the progressive load limiter working as a system has potential for increased safety by attracting increased usage by a large span of child occupant sizes together with a more adapted crash performance for the children age 4-12.

Paper No. 07-0205-O

Q3s 3 Year Old Side Impact Dummy Development

Michael Carlson, Michiel van Ratingen, *First Technology Safety Systems, United States*
Andy Barnes, Mark Burleigh, *First Technology Safety Systems, United Kingdom*
Kees Waagmeester, *First Technology Safety Systems, The Netherlands*

Abstract:
The Q3s dummy is a three year old child crash dummy optimized for side impact crash testing. The dummy is built on the platform of the standard Q3 dummy, that is part of the Q-series of child dummies developed in Europe to replace the P-series. Enhanced lateral biofidelity, durability and additional measurement channels have been designed into the Q3s dummy. The dummy features a new head that eliminates previously reported high frequency noise, an extensible neck that combines improved frontal

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flexion performance with the lateral and tensile performance of the Q series necks, a highly deformable shoulder with shoulder deflection measurement, a new arm with improved flesh characteristics, a laterally compliant chest and a pelvis with improved upper leg flesh, floating hip cups, and pubic load transducer. Biofidelity performance for the lateral 3 year old ATD is validated against the scaled biofidelity targets published by Irwin et al (STAPP 2002). This paper will describe the construction of the dummy and the laboratory biofidelity performance.

Paper No. 07-0145-O

Analysis Of Child Responses In CRS Using Child Human FE Model

Koji Mizuno, Tatsuya Namikiri, *Nagoya University, Japan*

Abstract:

To investigate injuries to various body regions of a child in detail using child restraint system (CRS), a finite element (FE) model of a 3-year-old child was developed by scaling from the AM50 human FE model, THUMS (Total HUman body for Safety). The dimensions of each body region were based on the anthropometry data of United States children, and material properties of child bone were estimated from data reported in the literature. The pelvis with child anatomical structure was represented in the model. Neck flexion, thorax impact responses and torso flexion were validated against the response corridor of the 3-year-old Hybrid III dummy in calibration tests.

ECE R44 sled impact test simulations for three different types of CRSs were conducted using the child human FE model and a Hybrid III FE model. For the child human FE model, whole spine flexed, whereas for the Hybrid III with stiff thorax spine, only the cervical spine and the lumber spine flexed. Loading to the cervical spine was higher for Hybrid III for all CRS types. In the 5-point harness CRS, the head down movement and its rotation were large for the child human FE model though injury criteria between two FE models were almost the same. In the tray shield CRS, chest deflection of the child human FE model was larger than Hybrid III. In the vest-type CRS, the neck of the child human FE model was interacted with the harness of the vest which can cause serious injury although for the Hybrid III neck injury criteria were less than thresholds.

The influence of CRS misuse on injury criteria was also examined. In the 5-point harness CRS, the injury risks increased according to the slack of the harness and seat belt. In the tray shield CRS, the injury criteria did not increase so much with seat belt slack, and this this CRS type was robust against CRS misuse.

Paper No. 07-0509-O

The Development And Application Of A Child Restraint Usability Rating System

Jocelyn Pedder, David Hillebrandt, *RONA Kinetics and Associates Ltd,. Canada*

Abstract:

This paper describes the development, validation and application of an “ease of use” rating system for child restraints and the design changes that have evolved.

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The rating system was developed in response to concerns about the high incidence of child restraint misuse and the potential for reduced protection during a collision. The objectives were to help consumers choose child restraints that are easier to use and to encourage manufacturers to improve the usability of their products.

A research program to develop the rating system was undertaken by RONA Kinetics with the support of the Insurance Corporation of British Columbia in Canada. It included participation by members of the ISO child restraint working group, regulatory authorities, vehicle and child restraint manufacturers, child passenger safety technicians, IIHS and consumers. A sample of some 30 child restraints (from N. America and Europe) was used to identify key child restraint use features that were ranked according to the risk of injury if misused. Objective criteria and tests for rating the individual features and a method for calculating the rating scores were developed.

The rating system was first used to rate 80 child restraints for ICBC consumer guides. It is the basis for the NHTSA child restraint ease of use rating program. It is being used in new ISO work related to the usability of ISOFIX (LATCH/UAS) features. Its current use and areas in which the rating system may be upgraded are considered.
The rating system provides an objective means of evaluating the usability of child restraints. It addresses features related to the safe use of child restraints that are not included in current regulations. Since its application, child restraint manufacturers have improved the usability of their products thereby reducing the risk of misuse and increased child passenger protection.

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Technical Session: Advances in Truck and Bus Safety

Oral Presentations | Thursday, June 21, 2007 | 9:00a.m.-12:00p.m.

Chairperson: Andrzej Szosland, Poland | Track C | Room: Salon Pasteur
Co-Chairperson: Mátyás Matolcsy, Hungary

Paper No. 07-0152-O
The Severity Of Bus Rollover Accidents
Mátyás Matolcsy, *Scientific Society of Mechanical Engineers, Hungary*

Abstract:
The most dangerous bus accident is the rollover. An accident statistics - collected by the author containing more then 300 accidents - shows that the average casualty rate is 25 casualties/accident. There are four major injury mechanisms in a rollover which may endanger the occupants: intrusion, projection, total and partial ejection. Different ways of protection may be used to avoid these kind of injuries, which are shown in the paper. The severity of a rollover accident may be specified on two different ways: one is based on the number of casualties (this is mainly used by the public opinion) and the other one evaluates the circumstances of the rollover (turn on side is less severe than roll down into a precipice) The severity is a basic parameter when specifying the protectable rollover accidents (PRA) in which the occupants may be and shall be protected. This severity limit may be defined on the basis of the accident statistics mentioned above and on the basis of in depth analysis of real world rollover accidents and different rollover tests. These methods are used and discussed in this paper. All bus passengers using different bus categories (traditional buses, high decker tourist coaches, double deckers, small buses) shall have the same safety level which shall be guarantied by international regulation. This paper is a contribution to the international effort specifying a general regulation about the safety of buses in rollover accidents.
The author of this paper is the chairmen of the international expert group dealing with this problem in Geneva (UN-ECE)

Paper No. 07-0477-O
Mass Transit Bus Vehicle Compatibility Evaluations During Frontal And Rear Collisions
Gerardo Olivares, Vikas Yadav, *Wichita State University, United States*

Abstract:
Mass transportation systems and specifically bus systems are a key element of the national transportation network. Buses are one of the safest forms of transportation. Nonetheless, bus crashes resulting in occupant injuries and fatalities do occur. Therefore, crashworthiness research is a continuing effort. Using funding from the Federal Transit Administration, Wichita State University is performing research to analyze and improve the crashworthiness of mass transit buses.

According to the Traffic Safety Facts reports from 1999-2003, an average of 40 fatalities and 18,430 injuries of bus occupants occurred per year. An average of 11 bus occupants per year are killed in two

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vehicle crashes while 162 occupants per year of other vehicles are killed (102 occupants in passenger cars, 49 in light trucks, 9 in motorcycles, and 2 in large trucks). For this period of time an average of 12,000 bus occupants per year are injured in two vehicle crashes while 8,800 occupants per year of other vehicles are injured (6,000 in passenger cars and 2,800 in light trucks).

Vehicle compatibility is an issue that needs to be addressed in order to reduce the number of fatalities and injuries to mass transit bus, and collision partner vehicle occupants. Crash incompatibility between vehicles has been attributed to three factors: mass, stiffness, and geometric incompatibilities. The objective of this research is to identify vehicle compatibility issues encountered during typical Mass Transit Bus collisions with sedans, light trucks, and heavy trucks through the use of numerical finite element simulations. The findings of this research can be used in the future by bus and vehicle manufacturers to improve crash compatibility.

Paper No. 07-0539-O

Laboratory Testing Program For F.E. Crash Analyses Of Paratransit Buses

Hongyi Li, Cezary Bojanowski , Jeff Siervogel, Jerry W. Wekezer, *Florida A&M University – Florida State University College of Engineering, United States*
Leslaw Kwasniewski*, Warsaw University of Technology, Jerzy W. Kownacki, Motor Transport Institute, Poland*

Abstract

An extensive validation program was developed and implemented in support of computational mechanics of paratransit buses. The program is based on laboratory testing of coupons for material characterization (test level 1, TL 1) and connection tests (TL 2). Experimental data obtained from TL 1 tests were used for development of the finite element (F.E.) models of several structural components and connections of a paratransit bus selected for this study. The segments, critical for crashworthiness performance of the entire bus, included: a wall-to-floor, a wall-to-roof, and a side-wall panel of the bus. Resistance functions, relating a force applied vs. resulting displacement, were developed for each component. They were obtained from experimental tests (at TL 2) and from computational mechanics F.E. analyses. Comparison of the resistance functions and the failure mechanisms provided a good validation of the F.E. models of the major structural components which, in turn, were included in F.E. models of the entire paratransit bus.

Two models of the paratransit bus, with 70,000 and 600,000 finite elements, were developed for crashworthiness and safety assessment of the bus. AutoCAD files, material samples and components for testing were provided by the bus manufacturer to aid in the model development and validation processes. The Ls-Dyna nonlinear commercial code was used as major tools for numerical analyses. Two impact scenarios were considered: a rollover of a bus from 800 mm, and a 90o side impact of the bus by a pickup truck at 48 km/h. The study revealed a significant stiffness of structural members used for the passenger compartment. However, the structural connections demonstrated disproportionally lower strength. Efforts are currently under way to provide an improved, crashworthy design with enhanced balance between stronger connections and weaker (lighter) structural members.

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Paper No. 07-0452-O

Passenger, Goods And Agricultural Vehicle Safety - Effectiveness Of Existing Measures And Ranking Of Future Priorities In The UK

Tanya Smith, Iain Knight, Jeremey Broughton, *TRL Ltd, United Kingdom*

Abstract:

Larger vehicles, such as goods vehicles with a gross vehicle weight in excess of 3500kg or passenger vehicles with more than 8 seats, are involved in fewer accidents per billion vehicle kilometers traveled than passenger cars. However these larger, heavier vehicles are involved in more fatal accidents per billion vehicle kilometers than passenger cars. Accident rates of 1.6 for large goods vehicles and 2.3 for large passenger vehicles compared with 0.9 for passenger cars are noted (RCGB, 2005).

The UK Department for Transport is currently reviewing its safety priorities for large goods vehicle and large passenger vehicles. Phase 1 of the review has included an extensive literature search to identify how previous changes in regulation have affected casualty figures and to identify the predicted benefits from previous research that has not been regulated for. Phase 2 of the review includes analysis of accident data, including STATS19 (GB national statistics), European CARE database and other UK based studies such as the Heavy Vehicle Crash Injury Study (HVCIS), Co-operative Crash Injury Study (CCIS) and the On-the-Spot (OTS) study. HVCIS is the only UK study that routinely collects nationally sampled accident data specifically relating to larger vehicles and plays a pivotal role in this review of safety priorities for large goods and large passenger vehicles.

The purpose of the project is to identify the most significant cost effective countermeasures for larger vehicles taking predicted casualty reduction, cost of implementation, technical feasibility and likely date of introduction into account. For the first time in the UK, statistical modeling techniques, which are currently used to predict national casualty reductions, are used specifically for the analysis of casualties caused in accidents involving larger vehicles.

This paper reports the findings of the analysis to date, including analysis of the HVCIS fatal accident database which contains over 1800 fatal accident cases involving larger vehicles. The analysis focuses on one of the key areas of interest that has been identified by this research.

Paper No. 07-0242-O

NHTSA Research Efforts To Significantly Improve Braking Performance Of Medium And Heavy Trucks

Riley Garrott, Ashley Dunn, *National Highway Traffic Safety Administration, United States*

Abstract:

Research Question: What improvements in dry, high-speed stopping performance can be expected from currently available brake technology on Class 8 trucks and truck tractors? What technical consequences should be expected from the increase in brake torque necessary to accomplish significant increases in stopping performance?

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Methods: Answers for the research questions were reached following coordinated simultaneous research in the areas of vehicle dynamics modeling and extensive on-vehicle and brake dynamometer performance testing by NHTSA engineers and research scientists.

Data Sources: Objective on-vehicle vehicle testing results, including wet and dry stopping distance, wet braking stability, and brake-in-curve stability evaluations, are discussed. Objective measurements of brake torque and hysteresis, measured on the NHTSA inertial brake dynamometer from speeds up to 70 mph, are presented. Analytical vehicle dynamics results are used to understand the effects that higher-torque brakes might have on braking stability for tractor-semitrailer rigs comprised of one or two trailers.

Conclusions: Extensive testing results have shown that a 30% reduction in dry stopping distances is possible for the vast majority of Class 8 trucks and truck tractors in North America, with no obvious degradation in other performance areas. Air Disc brakes make these improvements attainable with relatively small incremental cost to the end consumer. Unforeseen improvements include a 10% improvement in stopping distance during ABS-controlled stops on wet pavement, a result of significantly lower brake hysteresis with modern Air Disc brakes. Hybrid foundation brake configurations, utilizing larger, more powerful S-Cam drum brakes or Air Disc brakes on the steer axle only, are also shown to provide significant performance improvements over current foundation brakes. A significant potential setback in implementing this technology would be challenges from fitting larger S-Cam drum or Air Disc brakes into the current physical design envelope.

Paper No. 07-0290-O

Study Of Heavy Truck Air Disc Brake Effectiveness On The National Advanced Driving Simulator

Paul Grygier, W. Riley Garrott, *National Highway Traffic Safety Administration*
M. Kamel Salaani, *Transportation Research Center, Inc,*
Chris Schwarz, Tim Brown, Michelle Reyes, *National Advanced Driving Simulator*
Gary Heydinger, *Ohio State University, United States*

Abstract:

In crashes between heavy trucks and light vehicles, most of the fatalities are the occupants of the light vehicle. A reduction in heavy truck stopping distance should lead to a reduction in the number of crashes, the severity of crashes, and consequently the numbers of fatalities and injuries.

This study makes use of the National Advanced Driving Simulator (NADS). The dynamics model of the heavy truck found on NADS has been modified with the creation of two additional brake models. The first is a modified S-cam (larger drums and shoes) and the second is an air-actuated disc brake system. A sample of 108 CDL-licensed drivers was split evenly among the simulations using each of the three braking systems. The drivers were presented with four different emergency stopping situations. The effectiveness of each braking system was evaluated by first noting if a collision was avoided and if not the speed of the truck at the time of collision was recorded.

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The results of this study are expected to show that the drivers who used the air disc brakes will have fewer collisions in the emergency scenarios than those drivers using standard S-cam brakes or those using the enhanced S-cam brakes.

Paper No. 07-0485-O

An Ergonomics Evaluation Of The Safety Impact Of A New On-Board System: SAFEMAP

J.M Christian Bastien, Mathieu Beal, *Université René Descartes - Paris 5, France*
Laurent Jacques, *Volvo Technology Corporation*
Claude Covo, *Volvo 3P Advanced Engineering Dep.*
Marie-Line Gallenne, *LCPC, Spain*

Abstract:
The SafeMap project, part of the DEUFRAKO programme (a cooperation between France and Germany), aims at assessing the use of a dedicated digital map for road safety applications. The consortium includes car and trucks manufacturers, map providers, universities, and other research agencies. The objectives are to define the database content in regards to safety, benefits, and data provision costs, to assess the feasibility of map data provision, to optimize the data provision chain (public authorities and private companies contributions), to provide a demonstrator with this system embedded, to evaluate in-vehicle safety applications using digital maps and driver acceptability.
Based on criteria of safety effectiveness and ease of implementation/deployment, Volvo has developed the four following functions for trucks:

(A) Speed Limit Assistant: This function is similar to various systems studied in a series of Intelligent Speed Adaptation initiatives across Europe. The driver will be warned regarding map data and vehicle dynamics behaviour.

(B) Curve Speed Warning: The safe speed when negotiating a curve is computed from map data, which takes into account road characteristics, vehicle dynamics, and driver behaviour.

(C) Frequent Accident Spot Warning: Whenever the current driving conditions correspond to a combination of accident circumstances that have already been produced on the given road section, a warning is sent to the driver.

(D) Physical restrictions warning: The driver is warned or informed about physical restrictions along the road.

The aims of the present study are to assess the impact of information/warnings, and to evaluate the acceptability of the SafeMap system as implemented by Volvo on an instrumented truck. The experimentation phase is ongoing in cooperation between LAA and Volvo, and the results will be presented at the conference.

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Paper No. 07-0488-O

French Study To Enhance Passive And Active Safety On Military Vehicles

Vincent Denis, Philippe Cornu, Islem Hammouda, Hervé D'achon, Xavier Dissoubray,
TRININFOR
Vincent Schmitt, Christian Renou, Norbert Guiguen, *Etablissement technique d'Angers, France*

Abstract:
ETAS (Etalissement technique d'Angers), a French MoD expert for land systems within the French Defense Procurement Agency DGA (Délégation générale pour l'armement), launched a program currently still in progress aiming at reducing fatalities and damage due to traffic accidents involving military vehicles. Such vehicles were identified indeed as being subject to specific constraints bound to their particular operational use. The DGA and Trininfor (a subsidiary of the French technology consulting group Altran) have been thus conducting for nearly two years a joint study whose goal is:
to identify the main drivers of traffic accidents involving military vehicles over a statistical survey;
to identify and assess active and passive safety systems able to mitigate traffic accidents without altering military vehicles' operational capabilities;
to draw the specifications of safety demonstrators to be manufactured, implemented and tested later on.

Tasked by the DGA, Trininfor conducted the statistical survey using French Army data on traffic accidents in metropolitan France, overseas territory, and operational theatres (e.g. Kosovo and Ivory Coast). In the end of the survey, the results clearly showed that occupants in military vehicles run peculiar risks given specific use and design of such vehicles.

In order to identify relevant technical as well as feasible solutions, the DGA and Trininfor then established a state-of-the-art of active and passive safety systems. The results show that the emphasis shall be put on finding ways to improve:

- horizontal as well as vertical stability;
- traffic lights efficiency;
- intervehicle compatibility;
- occupants restraint systems' efficiency.

The main features that are taken into account are:

- technical feasibility;
- significant cost/efficiency ratio;
- potential reduction of the amount of public funds spent on MRO and compensations given to victims.

Technical specifications assessing the possibility of implementing these systems with a view to equipping military vehicles are eventually drawn.

The DGA's primary objectives while conducting this study are:

- to reduce fatalities;
- to reduce the overall cost of accidents (MRO + compensations) for MoD;
- to keep or to ameliorate operational capabilities.

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Paper No. 07-0135-O

Evaluating The Need For Changing Current Requirements Towards Increasing The Amount Of Lighting Devices Equipping Semi Trailers

Krzysztof Olejnik, *Motor Transport Institute, Poland*

Abstract:

The report has pointed out the need to provide the truck driver with a semi trailer the ability to see the contour of the semi trailer and road illumination in the insufficient lighting conditions. The need for equipping the vehicle with additional contour light and lamps illuminating the section of the road overrun by the semi trailer wheels has been assessed.

This is particularly important during manoeuvring with such truck – semi trailer unit at night to ensure safety, as the semi trailer has a different tracking circle than the towing truck. Current regulations are too (categorical) restrictive and limiting possibility of introducing additional lights. The proposal for technically solving this problem as well as amending the regulations has been presented. The existing technical requirements included in current regulations on lighting do not take into account the need to ensure the visibility of these areas for the truck driver with a semi trailer.

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Technical Session: Structural Integrity And Restraint Performance

Paper No. 07-0067-W

Effects Of Seat Belt Load Limiters On Driver Fatalities In Frontal Crashes Of Passenger Cars

Matthew Brumbelow, Bryan Baker, Joseph Nolan, *Insurance Institute for Highway Safety, United States*

Abstract:

In the mid-1990s, seat belt load-limiting devices were introduced on many new passenger vehicles equipped with front airbags. These devices are intended to reduce belt-induced injuries such as rib fractures by allowing forward movement of occupants' torsos when belt loads exceed some threshold. Load limiters have been shown to reduce thoracic injury risk in controlled experiments with cadavers and in full-width rigid barrier frontal crash tests.

The Insurance Institute for Highway Safety has evaluated many vehicles equipped with load limiters in 64.4 km/h (40 mi/h) frontal offset crash tests. Results indicate that in some crash circumstances the amount of forward movement allowed by load limiters could increase the risk of head injury from contacts with vehicle interior components. Thus, although load limiters perform well in rigid barrier tests with high deceleration, short duration, and low intrusion, the forward movement they allow in crashes with longer duration and higher intrusion may increase head injury risk.

To examine the effects of load limiters on driver fatality risk in real-world crashes, the present study compared rates of belted driver deaths per vehicle registration before and after load limiters were added to seat belts. Study vehicles were restricted to models with no other significant design changes. Fatality rate comparisons for passenger cars with and without load limiters suggest these devices have not reduced fatality risk and even may have increased the risk.

Also presented in this study is a review of a small number of cases from the National Automotive Sampling System that illustrate how increased occupant forward movement can contribute to head injury risk even in vehicles with front airbags.

Paper No. 07-0101-W

Injury Analysis Of Laminated And Tempered Side Glazing

Stephen Batzer, Chandra K. Thorbole, G. Grant Herndon, David Beltran, *Engineering Institute, United States*

Abstract:

The injury characteristics of tempered and laminated side glazing during collisions are analyzed. This study is based upon a comprehensive literature review, fundamental design analysis, and the results of numerous statistical studies with particular emphasis on the injury rates associated with the tempered and HPR laminated windscreens that were used concurrently in Europe in the late 1960s and 1970s. Comparative aspects of laceration, ejection, impact, eye injury, and entrapment are detailed. It is shown

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that the occupant is most seriously threatened by partial or complete ejection which can be effectively mitigated by laminated glazing. It is also shown that the most common glazing-related injury is laceration, the incidence of which is also reduced by laminated glazing. Injury statistics conclusively demonstrate that for each injury mechanism studied, laminated side glazing offers superior occupant protection. The relative merits of the two glazing materials are discussed from the cost, security, and comfort/convenience perspectives. The results of testing of currently marketed side glazing technology are also presented. The study is limited by the disproportionate use of tempered side glazing in vehicles on the roadway at the time of writing, and that instances of laminated side glazing preventing ejection related serious injuries are not fully reported. New contributions include the comprehensive nature of the study, testing, and analysis.

Paper No. 07-0141-W

The Benefits Of Basic Countermeasures To Reduce Rollover Casualties

Carl Nash, *George Washington University, United States*

Abstract:

This research provides new insight into the nature, causes and costs of serious to fatal rollover casualties; and the economic benefits of basic countermeasures. The National Accident Sampling System (NASS) is a rich source of data on motor vehicle crashes, particularly if one goes beyond the electronic files. In this work, the author reviewed every NASS case after 2001 in which a passenger car, SUV, pickup, or minivan that was less than eleven years old rolled over and produced an AIS 3+ injury (more than 700 cases). From this, we developed a useful new classification for these crashes with AIS 3+ injury: (1) cases with complete ejections, (2) cases in which there was a head or neck injury from roof crush, (3) other rollovers in which the rollover was the most harmful event, (4) cases in which a collision before the rollover was the most harmful event, and (5) cases in which a collision or major change in elevation during the rollover was the most harmful event. We used the NHTSA “Economic Impact of Motor Vehicle Crashes” and the weighting factor for the crashes to determine the total cost of all of these crash injuries. We then estimated the effectiveness of three basic countermeasures – a strong roof, side window glazing that does not break out during the rollover, and an effective belt use reminder – in reducing the severity and cost of these injuries. The results were most dramatic for SUVs where the discounted potential savings were on the order of several thousand dollars per vehicle over its lifetime. Even for passenger cars, the savings would easily justify the cost of these countermeasures. This work demonstrates the high degree of benefit that would far outweigh the cost of the countermeasures even if the affected vehicles were equipped with electronic stability systems.

Paper No. 07-0249-W

Crashworthiness Analysis Of Three Prototype Ambulance Vehicles

Nadine Levick, *Objective Safety LLC, United States*
Raphael Grzebieta, *Monash University, Australia*

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Abstract:
This paper presents an evaluation of the safety performance of three USA prototype ambulance vehicles with aftermarket structural modifications. Expected safety performance was analyzed using existing and established automotive safety principles. Detailed information on design and construction of the vehicles was identified, and evaluated via application of basic engineering crashworthiness principles and laws of physics, with a specific focus on countermeasure design for reducing harmful loading and injury causation potential in crashes or sudden decelerations. Data sources used for the analysis included: vehicle specifications, inspections, photographs, crash tests and published crashworthiness and injury mitigation literature.

Results demonstrated poor vehicle structural integrity and crashworthiness for these aftermarket modified ambulance vehicles. Assessed crashworthiness performance and occupant protection do not appear optimized even for the minimally structurally modified van. Current interior design features (seat design, patient transport device design, head strike zones and restraint systems) and layout, demonstrated predictable serious crashworthiness and occupant protection hazards.

These are projected findings, rather than actual crashworthiness tests – however this is the first comparative automotive safety evaluation of prototype ambulance vehicles. This is key information for a major fleet of vehicles globally which has had minimal automotive safety attention or input to date.

From this study it appears there are major deficiencies in safety design of these prototypes. Emphasis on effective seat design, based on existing literature and a clear focus on occupant human factors and equipment location and anchors, could provide for major safety enhancements for ambulance vehicles. There is need for vehicle safety researchers, ambulance industry and vehicle designers to recognize and apply these existing principles to reduce current system failures in an important and essential service that has a poor safety record well below that of passenger vehicles.

Paper No. 07-0371-W

Head And Neck Injury Potential In Inverted Impact Tests

Stephen Forrest, Steven Meyer, Andrew Cahill, *SAFE Research, LLC*
Brian Herbst, *SAFE Laboratories, LLC, United States*

Abstract:
NHTSA has concluded that there is a relationship between roof intrusion and the injury risk to belted occupants in rollovers [i]. Roof crush occurs and potentially contributes to serious or fatal occupant injury in 26% of rollovers [ii]. Occupant ejection (including partial ejection) is the leading cause of death and injury in rollover accidents. In fatal car accidents involving ejection, 34% were ejected through the side windows [iii]. Ensuring effective occupant restraint and retaining side window glass will reduce occupant ejections.

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The inverted drop test methodology is a test procedure to evaluate the structural integrity of roofs under loadings similar to those seen in real world rollovers. Drop test comparisons were performed on at least 16 pairs of production and reinforced vehicles representing a large spectrum of vehicle types. Significant roof structure deformation is shown to enhance potential ejection portals and alter restraint geometry/ performance, while increased structural integrity is shown to maintain occupant survival space, seat belt geometry and contribute to side glazing retention.

This paper offers several examples of post-production reinforcements that significantly increase the crush resistance of the roof as measured by inverted drop tests. These modifications were implemented with minimal impact on vehicle styling, interior space and visual clearances, and indicate that roof crush can be reduced 44-91% with only a 1–2.3% increase in vehicle weight. This paper analyzes inverted drop testing performed on several production and reinforced matched vehicles with restrained Hybrid III test dummies. Review of neck load data indicates that reduced roof crush results in a direct reduction in neck load, thereby increasing occupant protection. Restraint loading and performance, relating to roof structure integrity, is also evaluated.

Paper No. 07-0378-W

Parametric Analysis Of Rollover Occupant Protection Using A Deformable Occupant Compartment Testing Device

Brian Herbst, *SAFE Laboratories, LLC*
Stephen Forrest, Steven Meyer, *SAFE Research, LLC, United States*

Abstract:
Occupant kinematics during rollover/ inverted impacts have been the subject of significant research. Controlled experiments have utilized complete vehicles, partial vehicles and seat/restraint systems attached to various platforms. The Deformable Occupant Compartment Impact Tester (DOCIT) was developed to incorporate functions similar to previous methods, but has added a roof capable of deforming under impact. Roof deformation characteristics can be reset without the destruction of a complete vehicle. The DOCIT simulates an occupant compartment (roof, seat, restraint system) in which an ATD is placed and subjected to a repeatable inverted dynamic impact environment. Several test series are reviewed, in which baseline tests, based upon real-world rollover accidents, are compared with alternate design systems under the same impact environments. 5th and 50th percentile Hybrid III's are utilized to assess neck/ head injury criteria. Alternate designs for roof structures and restraint systems are tested to determine the effectiveness of each.
The DOCIT accomodates rapid parametric analyses of occupant injury criteria relative to various occupant, restraint and roof configurations in a dynamic loading environment and enables evaluation of restraint system performance and injury potential under impacts with controlled initial/ residual head clearance and repeatable pre-determined roof profiles. Test variations in restraint systems or roof performance can be correlated with other component/ full vehicle tests without the need for the destruction of many vehicles.
This research indicates that for reasonably restrained occupants:

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Roof crush preceded head to roof contact and peak neck forces.
Reducing roof crush reduced neck injury measures and therefore neck injury potential.
Reducing roof crush/ optimizing restraint designs eliminated interaction with the roof and provided correspondingly negligible injury measures.

Paper No. 07-0394-W

Rollover Crashes: Diving Versus Roof Crush

David Young, Raphael Grzebieta, Mike Bambach, *Department of Civil Engineering, Monash University*
Andrew McIntosh, *School of Safety Science, The University of New South Wales, Australia*

Abstract:
This paper considers the effectiveness of roof structural integrity combined with restraint performance in rollover crashes to mitigate serious AIS 5 neck injuries. A rational analysis of the two apparently conflicting views of neck injury causation for contained and belted occupants in rollover crashes that have been presented in research literature to date, i.e. torso augmentation (diving) vs. roof intrusion, is presented. The validity of each of the views and associated injury causation mechanisms and underlying concepts are investigated using basic physics. Neck injury results from GM's rollover Malibu II test series are then reanalysed in light of the findings using the NHTSA Neck Injury Criterion (Nij). The neck loadings are also compared to recorded Hybrid III neck loadings measured by the authors in some typical physical events that a person may become involved in, but considered not particularly injurious in regards to resulting in serious spinal injuries.

The paper argues and proves that complete quadriplegia or paraplegia AIS 5 neck injuries having a 40% or more probability of injury, only occur in the GM Malibu II non-reinforced production vehicles. It will also demonstrate using Newtonian laws of physics and plastic mechanism theory how buckling of the roof can result in the higher intrusion velocities necessary to incur the AIS 5 neck injuries. Whilst the authors accept torso augmentation can occur, they will demonstrate via MADYMO computer simulations and theoretical calculations, that when an occupant is properly restrained in a pretensioned 3 point seat belt in a vehicle with adequate roof strength and head clearance, the critical drop impact height can be raised from 0.5 metres to well over many metres. The implications of this finding are that rollover crashes even up to freeway speeds can be readily designed with minimal additional cost, to be non injurious events.

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Technical Session: Developments in Side and Frontal Impact Protection

Paper No. 07-0185-W

Use Of High Efficient Energy Absorption Foam In Side Impact Padding

Gerhard Slik, Gavin Vogel, *Dow Automotive, Germany*

Abstract:

In side impact events padding is used to absorb energy on one hand and push the dummy into motion on the other. The padding is usually applied in the pelvic, the abdomen and the thorax area. The amount of absorption versus push load is important to obtain acceptable levels of the injury parameters as stipulated by legislation (e.g. ECE R95, FMVSS 214) and consumer tests (e.g. EURO/US-NCAP and IIHS). Practice shows many types of foam padding designs which fulfil the requirements, often in combination with side airbags.

In this paper the advantage of applying high efficient energy absorption foams in padding is presented. This enables designers of passive safety systems not only to save space, weight and cost but also increase safety (ratings) by having a better defined and easier tune-able loading system on the dummy during side impact crashes. A specific FEA simulation methodology has been developed to optimize part design. Results and test cases are discussed showing the benefits of high efficient energy absorption foam padding.

Paper No. 07-0208-W

Curtain Airbag Gas Delivery System Development Using CFD Analysis

Hyunsok Pang, Joseph Massa, *Key Safety Systems, United States*

Abstract:

This paper describes curtain airbag gas delivery system development work using CFD analysis. The objective of developing gas delivery system was to achieve uniform inflation and reasonable time to position for oblique pole test with 5th %ile female. CFD analysis has been conducted to design gas delivery system of 3 row curtain airbag. The gas delivery system consists of T-diffuser and flexible gas delivery tube. T-diffuser hole sizes, the number of holes and hole locations in flexible gas delivery tube system have been determined through CFD simulations. Confirmation static deployment test has been conducted to confirm the design specification from CFD analysis. In the static deployment test, pressure ports were installed to measure the pressures at several locations in the curtain airbag. It was found that the bag kinematics and pressures in the test were close to the simulation kinematics and results.

Paper No. 07-0211-W

An Overview Of NHTSA's Crash Reconstruction Software Winsmash

Dinesh Sharma, John Brophy, Seymour Stern, *National Highway Traffic Safety Administration*
Eun-Ha Choi, *Rainbow Technology, United States*

Abstract:

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The National Highway Traffic Safety Administration (NHTSA) uses WinSMASH computer software to estimate the change in velocity, delta-V, of the vehicles involved in crashes. The software uses detailed measurements from the crash scene and vehicle damage and vehicle stiffness characteristics to compute energy absorbed by the vehicle and estimate the Delta-V and Barrier Equivalent Speed (BES). The WinSMASH is a Microsoft based enhanced and updated version of the accident reconstruction software CRASH 3 previously used by NHTSA. The purpose of this paper is to describe the new enhancements in the program.

The damage algorithm used in CRASH 3 has been reformulated in WinSMASH. The new damage algorithm in WinSMASH is based on an assumed linear relationship between crash energy and crush and uses intercept d0 and slope d1 to describe vehicle stiffness. The software uses generic vehicle size and stiffness categories based on the size of vehicle wheelbase. However, the program allows the users to enter the vehicle specific stiffness coefficients. The stiffness coefficients for a large number of vehicles have been calculated from crash test results and integrated into WinSMASH. An automated procedure to select the vehicle specific stiffness coefficients is being developed. A statistical model is also being developed for estimating the stiffness coefficients of a vehicle that is not crash tested. The paper provides an overview of these procedures.

The WinSmash estimated delta-V of the vehicles is compared with the corresponding delta-V obtained from the OEM Even Data Recorder (EDR) installed in the crashed vehicles to assess the accuracy of the software. The staged crash tests used to validate the software are discussed in the paper.

Paper No. 07-0240-W

Offset Test Design And Preliminary Results

James Saunders, Aloke Prasad, Allison Louden, *National Highway Traffic Safety Administration, United States*

Abstract:

The National Highway Traffic Safety Administration (NHTSA) is conducting a research program to investigate options to improve the FMVSS No. 208 40 percent offset deformable barrier (ODB) crash test. The focus of the program is to reduce debilitating lower extremity injuries in frontal offset collisions. This paper discusses three areas of research in this program: a new seating procedure to better measure lower extremity injury, preliminary results of the crash test using the new procedure, and vehicle frontal stiffness changes due to redesign for offset tests.

The new test procedure uses Hybrid III male dummies fitted with Thor-LX legs. The development of a test procedure that has repeatable positioning of the Thor-LX feet with respect to the pedals in some vehicles was a particularly challenging problem. The test results show a primary failure mode of ankle inversion/eversion, and the mechanics of this failure will be discussed.

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Preliminary data are presented that suggest that both passenger cars and light trucks and vans (LTVs) are designed stiffer to meet offset test requirements. The potential impact of this on the compatibility of the light vehicle fleet will be discussed.

Paper No. 07-0259-W

Axial Collapse Of Square Tubes With Short Length

Shigeru Ogawa, Noriaki Ito, Michinari Watanabe, Arihiro Furumoto, Masatoki Kito, *Mazda Motor Corporation*
Dai-Heng Chen, *Tokyo University of Science*
Shigeyuki Haruyama, *Fukuoka Industrial Technology Center, Japan*

Abstract:
In order to reduce high impact load occurring in axial collapse of a crush can, which is installed in the front part of car, the elastoplastic nonlinear behavior of short thin-walled frusta with square cross-section subjected to statically axial compression is studied by using finite element method.

The square tubes 18mm in thickness, with upper cross-section of 85mm x 90mm and lower cross-section of 130mm x 135 mm, have different lengths ranging from 135mm to 225mm. A typical tensile stress-strain curve for aluminum is modeled as 2 straight-line hardening relationship.

The FEM code MSC.Marc is used to simulate the axial compression of thin-walled frusta of square cross-section. The load-displacement curves of frusta are obtained from the numerical analyses. It is found from the curves that in the axial collapse process of the frusta there are two peaks of the load, corresponding to the initial buckling and formation of the second wrinkle. Unlike the axial collapse of long tubes, however, the load due to the second wrinkle is higher in magnitude than the initial buckling load. The reason for high second peak load is that the frusta are too short to form the 2nd wrinkle.

The second peak load is very sensitive to the boundary condition on the lower end. Usually, high load occurs in a strong restraint.

Also, it is found the effects of holes in side plate of frusta on the second peak load are very complex. If the holes were located exactly right on the folding lobes, the second peak load could be reduced. The other methods to reduce the second peak load were also investigated. It seems that the most effective method for lowering load is shortening the wavelength of wrinkles.

Paper No. 07-0299-W

The Development Of The New Generation Barrier Face For Side Impact Test

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Japan Automobile Research Institute
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Japan Automobile Manufacturers Association, Inc.
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Abstract:
The barrier face that the current regulation was developed in the characteristics of '70s vehicle. So that, the characteristics is different from the current vehicle that conforms to the frontal impact tests and considering of compatibility. So, We did the development of the new barrier face that the characteristics of the current vehicles were reproduced.

First, we investigated the characteristics of the front-end of the vehicle for 1998MY. Next, we started the development of the barrier face in based on the results of this investigation. In the same time, they started the development of new barrier face in Europe. So, we cooperated with their development for harmonization.

The developed barrier face named AE-MDB is the almost matched to the characteristics of investigated results of current vehicles. However, the deformation mode was different between the car-to-car test and the MDB-to-car test. Therefore, we did more improvement in the barrier face. The improvement items were the addition of the beam element and the tuning of the stiffness of lower row. The beam element is reproduced the bumper reinforcement. In these improvements, we completed the development of the new barrier face that matched to the characteristics of the current vehicle, and the same deformation mode between the car-to-car test and the MDB-to-car test.

We hope that this barrier face is adopted in the new regulations for side impact.

Paper No. 07-0340-W

Influence Of HIII 5% Dummy Tolerances On Positioning And Test Results In Out-Of-Position Load Cases According To The FMVSS 208

Steffen Sohr, Heiko Ruck, Heiko Hofmann, Sascha Kutschenreuter, *Takata-Petri AG, Germany*

Abstract:
With the introduction of the FMVSS 208 Final Rule, the requirements for occupant protection systems in frontal crashes have significantly increased. Especially the requirements regarding the airbag aggressiveness for “Low Risk Deployment” pose new challenges for both automobile manufacturers and suppliers.

The testing procedure detailed in § S26 of the FMVSS 208 is commonly referred to as “Out-of-Position” (OoP). This procedure considers the HIII 5% dummy on the driver side for two different positions (position 1: “Chin on Module”, position 2: “Chin on Rim”).

With the applied testing method, the test setup allows tolerances regarding the dummy positioning relative to the vehicle environment.
A comprehensive analysis of the influence of the dummy positioning has shown that particularly the head angle can vary among dummy manufacturers and may result in different OoP load characteristics. Beside tolerances caused by the airbag module and the steering wheel design itself, the dummy’s head angle is a significant factor for a variation of the OoP test results.

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Out-of-position tests with identical module design have shown that the dummy positioning resulting from the head angle can lead to a misinterpretation of the test results. Depending on the dummy position, the OoP results range from far below the legal limits up to exceeding them.
During the module development process, this scope of interpretations dramatically affects the assessment of the OoP performance and may lead to wrong conclusions.

This paper wants to show that with a robust and OoP-optimized airbag design, it is possible to fulfil the "Low Risk Deployment" requirements of the FMVSS 208 independent from dummy positioning and different head angles.

Paper No. 07-0368-W

Intrusion Based Crash Sensing And Discrimination With Application To Adaptive Side Impact Restraints

Leonard Cech, Jialou Hu, Markus Schiefele, Henk Helleman, Debby Rice*, TK Holdings Inc., United States*
Benedikt Heudorfer, Michael Kraft, *Takata-Petri AG, Germany*

Abstract:
State of the art frontal airbag systems provide adaptive features such as multi-stage deployment and active or passive venting based on occupant position, stature, crash mode and severity. Research was done to understand the potential of reducing injuries and fatalities by applying a similar methodology to side impact protection.

Adaptive restraints have been proposed for side impact protection, however, the sensors and discrimination methods available for side crash detection, have, in general, not provided sufficient time and information to effectively apply these adaptations. However, recent analysis of an alternative Magnetic Side Impact (MSI) crash sensor has shown that this sensing concept provides crash mode and severity at sufficiently fast times to allow a second triggering event for situation adapted protection. Using CAE tools it is shown how the improved triggering times can be employed and how protection benefits may be gained by using various active adaptive restraint concepts.

To demonstrate the concept, MSI sensor data was analyzed for a series of crash and abuse tests to determine estimates of crash severity and mode at practical airbag deployment times for several deployment situations. The paper reviews the techniques used to process MSI sensor data, example derived deployment times, and the estimated crash modes and severity levels. Using this data, CAE analysis is shown to demonstrate the effectiveness of several candidate active adaptive restraints compared with standard restraints.

In conclusion it is seen that adaptive side protection is worth considering, not only because the future requirements are expected to become more complex and demanding, but also because the benefits can

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be considerable. However, improved systems do not come free of cost and therefore the pros and cons will have to be well balanced.

Paper No. 07-0372-W

Side Impact Injury Prediction With Fe Simulations Of The New Advanced World Sid Fe Dummy Models

Yi Liu, Fuchun Zhu, Zhenwen Wang, Michiel Ratinggen, *First Technology Safety Systems, Inc., United States*

Abstract:

Side impact collisions account for one of the highest fatality rate in all kinds of vehicle crash. The regulators around the world are reviewing the need for an updated side impact regulation that could be more effective. The World SID project is a global effort to design new side impact dummies, namely the WorldSID 50th and 5th, under the ISO, being considered for a worldwide harmonized side impact crash test regulation.

The World SID 50th physical dummy has been evaluated by the regulators and organizations worldwide against the current 50th percentile male side impact dummies in order to compare the bio-fidelity ratings. As a result, the World SID 50th achieved the best overall dummy rating and also the best single body region ratings. The World SID 50th dummy exhibits a more human-like response in a crash event.

World SID 5th was also developed under the direction of the ISO which represents a woman of small stature and a young adolescent. Both the World SID dummies will provide the foundation for future common and internationally accepted regulatory test procedures and enable automakers and researchers to improve passenger safety by facilitating the comparison of crash test results worldwide

This paper describes the development of new advanced Finite Element (FE) models of the World SID dummies and how the models were validated at material, component & assembly, full dummy certification and sled test application levels.

This paper also describes and how the dummy models can be used as a tool to predict the side impact injury and the procedures to use it in crash simulation. Typical occupant injury criteria can be obtained with the use of the dummy models for FMVSS 214 pole impact and moving deformable barrier (MDB) impact. The FE result predictions are compared with certification tests, bio-fidelity sled tests. Comparisons between the World SID dummy models and other side impact dummy models were also been made and summarized.

Paper No. 07-0416-W

Status Report Of EEVC WG 21 Accident Studies

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Yves Page, *Laboratoire d'Accidentologie, de Biomécanique et d'études du comportement humain*
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Dietmar Otte, *Medical University of Hanover*
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Matteo Giunti, *Fiat, Italy*
Boudewijn Hoogvelt, *TNO, The Netherlands*
Patrick Magnusson, *SNRA, Sweden*
Javier Paez, *INSIA, Spain*

Abstract:
Working Group 21, Accident Studies, has been formed to bring together analysis of existing accident data in support of the work programme of the EEVC. Its members represent all of the major in-depth accident databases in Europe and have access to a large number of others. This paper presents some of its early work.

A major task has been to conduct an audit of the available accident databases and to record their key characteristics. A total of 45 accident databases from 8 countries are identified and the paper lists factors including proprietary, data content, selection criteria, vehicles studied and purpose of investigation.

In general larger quantities of accident data are more likely to give statistically significant results and a second objective of the group has been to evaluate the feasibility and analysis potential of combining data from several countries. A pilot study was conducted to combine data from France, Germany and the UK to estimate the effectiveness of side airbag systems. A logistic regression model showed side thorax airbags reduced AIS 2+ thoracic injuries by 17%, although this was not statistically significant. A case based assessment of the sidebag effectiveness in selected accident situations was also conducted. The paper presents an overview of the results of this work and identifies several constraining factors.

In support of WG 12, biomechanics, WG 21 has been asked to provide data on the types of leg injury sustained in crashes by occupants of three different age groups of cars in relation to future designs of ATD. A parallel analysis of French, UK and German data is presented which shows the changes in lower extremity injury location and type.

Finally the paper will describe the current work of the group which is to assist the new work plan of WG 13, Side Impact Protection in relation to the further development of test procedures and side impact barrier characteristics.

Paper No. 07-0476-W

Development Of A DOE/Optimization CAE Method To Simultaneously Improve Side Impact Occupant Restraint System Performance For Multiple Test Modes

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Abstract:
The automotive industry today faces the challenge of developing a single side impact occupant restraint system to meet performance requirements for multiple crashworthiness test modes. The side air bag, door liner, and vehicle side body structure are the key systems that affect the injury criteria of the occupant. This paper discusses how design of experiment/optimization method is used to quickly develop a specification for the side air bag and door liner that meets occupant injury criteria for three different side impact test modes. The work detailed in this paper focuses on occupant protection assessment based on three different CAE side impact sled models using SID-2s, DOT-SID, and ES2-re dummy models to evaluate the SICE, current and proposed FMVSS 214 test modes.

Ten design variables were selected from air bag and door liner parameters which include mass flow rates, vent areas, two variables that define the location of the bag, and material/thickness of the door liner. Occupant injury parameters such as rib deflections/accelerations, pelvis accelerations/forces, and abdomen forces were selected as the responses. As first step, a latin hypercube DOE method is used to evaluate sensitivity of the design variables to occupant injury parameters. Based on the DOE's dominant design variables optimization criteria and methods were established for the next step. Key injury criteria for each test mode were selected as the constraints. A self adaptive evolution global optimization method was used to carry out automated simultaneous simulations . Based on the optimization results eleven feasible design specifications were found. Out of these candidates the optimum design was selected for further evaluation.

Paper No. 07-0480-W

Technologies To Improve Impact Related Fire Safety

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Abstract:
During the past 5 years, the Motor Vehicle Fire Research Institute has conducted extensive research to understand the conditions that produce crash induced fires in motor vehicles. Between 1975 and 1999 there has been a decline in the crash induced fire rate and the fire fatality rate. Since 1999 the fire rate for all passenger vehicle classes has been about the same and remained constant. At present there are about 450 deaths annually reported in FARS where fire is the most harmful event.

The prime regulatory emphasis during the past decade has been on an increased severity rear impact test for fuel containment. Rear impact is now associated with about 10% of the major (NASS) fires and FARS fires.

Current data shows that frontal impact has become the dominant crash mode for both major (NASS) fires and FARS fires where fire was the most harmful event. Rollover is the second highest crash mode for major fires and it carries the highest fire risk. The combination of frontal and rollover accounts for about 70% of the major fires. In both frontal crashes and rollovers, about 65% of the fires originate under the

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hood. The paper will summarize the findings from NASS and FARS regarding the distribution of fires by crash mode and fire origin.

An impediment to the development and implementation of fire safety countermeasures is the absence of an objective test procedure for evaluating their efficacy. The paper will summarize test procedures used by MVFRI, GM, NIST and others to evaluate underhood fire suppression systems such as the University of Maryland's aqueous foam system and the Fire Foe passive tubular system. It will also suggest additional test procedures to evaluate the Fireworthiness (occupant survivability) of vehicles when exposed to underbody fuel fires and underhood fires.

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Paper No. 07-0118-W

The Electronic Belt-Fit Test Device (eBTD): Activity Update

Dr. Joseph Hassan, *DaimlerChrysler*
Jochen Balzulat, *Human Solutions*
Thomas Carr, *Alliance for Automobile Manufacturers*
Suzanne Tylko, *Transport Canada, Canada*

Abstract:
The single most effective automotive safety component that has been proven to save lives during a crash is a properly fitted seat belt. Transport Canada introduced the concept of assessing seatbelt fit for occupants in the early seventies. A Beltfit Test Device (BTD) was then developed to measure and assess this fit. Research was sponsored by Transport Canada to quantify the proper limits of certain scales on the device that are considered to represent proper beltfit.
To overcome the deviations of hardware tests and to allow evaluations of belt designs early in design phases, the Alliance of Automobile Manufacturers supported the development of a computer modeling and simulation approach, also known as the electronic Belt Fit Test Device (eBTD), through a technical working group (TWG). That group includes representatives from the automobile manufacturers, Transport Canada and the software developer. The development takes place in close co-operation with the Transport Canada Joint Working Group – Abdominal Injury Reduction (JWG-AIR).
The computer model can be used at the design stage to assess the beltfit criteria developed using the BTD. This model, can not only be used as a basis for certifying seat beltfit to the regulatory criteria after the vehicle has been built, but can also be used as an effective design tool for restraint systems.
Recently, the development of the TWG achieved a milestone in the form of phase-1 “MOU” or Memorandum Of Understanding between Transport Canada and various automobile manufacturers. This MOU, addressing the beltfit for front seat outboard seating positions, establishes the first collaborative effort between a regulatory agency (Transport Canada) and automotive manufacturers to use computer modeling and simulation in place of physical measuring devices, to evaluate a safety concept. This paper describes this effort and highlights the results.

Paper No. 07-0154-W

Mass-Based Considerations For Head Injury Protection Development

Brian Boggess, Grant Foreman, *Honda R&D Americas, Inc., United States*

Abstract:
The purpose of this research study is to understand the mass limits of typical instrument panel (IP) components given standard design guidelines for head injury risk reduction. The IP components of passenger vehicles are continually improved to increase features and overall quality, which consequently increase the mass of these components. It was hypothesized that regardless of the mounting, certain IP components possess significant inertial resistance such that injury risk values may be above accepted

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risk levels without modification to their typical internal structures. Using the FMVSS201 test procedure, multiple IP components from several vehicles (n=6) were measured for head injury risk both in-vehicle and as excised suspended systems. The excised components were mounted using a simple pendulum setup with the component properly oriented and suspended from 2m cables and then impacted with a linear head impactor. Initial results showed that in an excised state, the injury values, both peak and 3ms clip deceleration, correspond to as much as 90% of the in-vehicle tested values. From the component and in-vehicle tests, work functions based on the component mass were developed to replicate the impact event and establish mass-based thresholds. Models studied included waveforms comprised of haversine, half-sine, triangular, trapezoidal and square functions. Haversine functions showed the highest correlation (R2 = 0.93). Initial assessment of the model showed the energy associated with an impact to a typical 4.2kg component is high enough to potentially exceed the acceptable injury risk values according to Federal regulations. Furthermore, integrated structures such as air bag modules have a lower mass threshold due to their mounting with the IP and stiffer housing for deployment requirements. Due to these thresholds, some design guidelines to improve the crush characteristics of structures such as radios, HVAC controllers, and air bag modules are presented.
Summary: Radio assemblies and other modules in the instrument panel continually are increased in mass due to additional features and electronics. Therefore, typical design guidelines for complying with applicable regulations must be adjusted to combat the ever increasing mass. This research derives the reasonable mass thresholds based on component testing and spring/mass models for the typical design methods, as well as presents design options to apply heavier modules.

Paper No. 07-0174-W

Simultaneous Evaluation Of Multiple Safety Functions In Passenger Vehicles

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Yves Page, *PSA*
Sophie Cuny, *Centre Européen d'Etudes de Sécurité et d'Analyse des Risques, France*

Abstract:
Up to now quite a few electronic safety functions have been developed in order to successfully increase the safety of passenger in vehicles. Among them are electronic stability programs (ESP), brake assists (BAS), lane departure warning systems (LDW) and so one. There exists a large literature on the quantification of the effectiveness of such safety systems on injury outcome or accident severity. As an example the ESP in several studies impressively has been shown to be efficient in avoiding loss of control or skidding accidents. Nowadays many recently registered vehicles are equipped not only with one but instead with a number of safety functions (so-called safety equipment). The present paper proposes sound statistical methodology in order to investigate the safety benefit of such composite safety equipments (in contrast to a single safety function) in passenger vehicles. It seems obvious that the effectiveness of a specific safety equipment not simply is the additive superposition of the effectiveness of the safety functions of which it consists. For example one may be interested in the additional or incremental effect on severe accidents of an airbag or a brake assist when an electronic stability program already is on board.

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The developed methodology will be applied to accident data from the German In-Depth Accident Study (GIDAS) which covers in great detail accidents with passenger injuries in the region of Hanover and Dresden in Germany. We have a sample of approximately 19'000 accidents for a five years period. The application of methodology is twofold. On one hand we make use of the in-depth data (case by case) itself and on the other hand, we make use of aggregated accident data, which more easily seem to be available, only.

The study has been carried through within the research program on Traffic Accident Causation in Europe (TRACE).

Paper No. 07-0247-W

In-Vehicle Intelligent Speed Limit Advisory Systems

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Michael Griffiths, *Road Safety Solutions*
George Germanos, *Smart Car Technologies, Australia*

Abstract:
Objective: To assess the potential road safety benefits of intelligent speed advisory systems

Methods: Review research findings on intelligent speed adaptation. Estimate the proportion of accidents involving unintentional speeding. Evaluate a prototype self-contained, on-board speed advisory system that alerts drivers when the prevailing speed limit is exceeded. Estimate the potential benefits of widespread use of the system. Assess the application of the technology to mandatory speed control systems.

Data source: Australian estimates of the proportion of speed-related crashes, based on police-reported and in-depth accident studies. On road trials of a prototype intelligent speed advisory system.

Expected results: Preliminary estimates suggest a potential to save around 10% of fatal crashes through a voluntary intelligent speed advisory system.

Conclusions: There are significant road safety benefits through the voluntary use of intelligent speed advisory systems. More than 99% of kilometres travelled with the prototype system were accurate for prevailing speed limit and vehicle speed and this is acceptable for an advisory system. However, the small number of false alarms and inaccuracies suggest that enhanced technology is required for a mandatory speed control system.

Discussion: Methods of implementing a national intelligent speed advisory system are discussed. Potential for integration with vehicle electronics are also discussed.

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Limitations of study: Estimates of accident savings apply to Australian conditions. The trial of the prototype system was limited to the Sydney metropolitan area.

Innovation: The prototype system uses GPS geographic information and a database of speed limits to alert drivers when they exceed the speed limit. This technology can be implemented through a variety of devices, including Personal Digital Assistants (PDAs) making it highly portable and suitable for voluntary implementation.

Paper No. 07-0284-W

An Analysis Of Violations Associated With Intersection-Crossing-Path Crashes

Raja Ranganathan, *URC Enterprises, Inc.*
H.Kerrin Bressant, *National Highway Transportation Safety Administration, United States*

Abstract:
This paper identifies and analyzes violations associated with intersection crossing path crashes for the purpose of providing support for deployment of effective countermeasure systems. The methodology begins by addressing multi-vehicle crashes at intersection / intersection-related junctions which are subdivided by their respective traffic control devices. This is followed by translating crashes into subsets of two-vehicle crossing path crashes and analyzing them in detail for their respective violations at various traffic control devices.
The analysis utilizes 2004 General Estimating System (GES) national crash data-files to arrive at the quantitative estimates. There were 1,055,000 two-vehicle crossing path crashes at intersections. A majority of the crashes involved vehicles at Straight crossing paths followed by vehicles at Left turn across path / Opposite direction and Left turn across path / Lateral direction. The major contributors for violations were 'Failure to Yield', which is due to the misjudgment of gap, and 'Running a red light /stop sign'. Nearly half the crashes were at signalized intersections and the remaining at non-signalized intersections. For vehicles at stop signs, a majority of them were at a two-way stop sign.
The paper uses a novel approach by addressing pairs of vehicles and their interactions with each other at crossing paths. The paper approaches violations from the perspective of looking at the number of violating vehicles involved in each multi-vehicle crash situation. Pre-Crash Movement, Critical Event, and the type of Traffic Control Device are utilized to help identify the violating vehicle in each of these situations.

Paper No. 07-0306-W

New Requirements Relating To The Provision Of Assistance To Road-Accident Victims: Recent Developments In France

Franck Batocchi, Céline Adalian, *PSA Peugeot Citroën, France*

Abstract:
In 2002, following the deaths of a number of firefighters attending road-accident scenes, the French Interior Minister Nicolas Sarkozy asked Colonel Pourny of the fire department to "conduct an analysis of

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the full range of missions carried out by firefighters and put forward proposals aimed at improving active and passive safety on the ground".

In light of the recommendations of the "Pourny report", the French defense and civil-protection directorate or DDSC (Direction de la Défense et de la Sécurité Civile), decided to set up a joint working group with French car manufacturers.

The group – which was initiated in the spring of 2005 – was required to drive progress in respect of the methods employed by teams working on damaged vehicles at accident scenes, the aim being to facilitate rescue work and enhance firefighter safety. Such progress is all the more essential given that recent vehicles (and notably coupe-cabriolets) are increasingly difficult to cut because of the reinforcements and resistant materials used to protect passengers in the event of an impact.

After a year's collaboration, the working group decided to focus on two complementary initiatives:
- The creation of "card for extraction" for distribution to French firefighters,
- The organization of extraction exercises for active-service firefighters, using recent vehicles.

A detailed, illustrated presentation will be made of each of these initiatives, thereby raising awareness of the technical information contained in the extrication sheets distributed to French firefighters since July 2006. Details of pilot exercises will also be provided.

Paper No. 07-0343-W

Automatic Emergency Calls In France

Cyril Chauvel, *Laboratory for the study of accidents, biomechanics and human behaviour - LAB*
Stephan Cayet, *PSA Peugeot Citroën, France*

Abstract:
In Europe, during 2004, 1,7 million people were injured in road accidents and 43,500 were killed. Fast and effective care of polytraumatized people by the emergency services can reduce the number of those seriously injured and killed.

An automatic emergency call system has been installed on PSA passenger cars in France and in six other European countries. It is an integrated car radio/GSM/GPS system that can be used with a SIM card. When an accident occurs, a call is sent automatically to a telephone call centre. Knowing the geographic location, the vehicle and owner identity and the possibility of communicating directly with the persons involved enables the nearest emergency services to be called out.

In this context, the LAB has set up a study aimed at evaluating the effectiveness of these systems. It consists of:

- an accident analysis study

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- a questionnaire, sent to persons involved, aimed at estimating the time saved to get to the scene
- a judgement of the emotional reassurance brought to the vehicle occupants

During the system's first years of operation, about forty cases have been studied in detail, using accident analysis investigation procedures.

The initial findings show that pinpointing the exact accident location enables the emergency services to reach the scene very quickly. In addition, some important vehicles characteristics are transmitted to them. A future system improvement could be the calculation of the accident's severity, the impact type and the number of people involved.

The development of this automatic call equipment should continue in France and in Europe. It will be an additional tool in the fight against road injury and death, particularly for accidents at night, involving single vehicles and in isolated areas. The purpose of this article is to explain the method of investigation used and present the first experimental feedback.

Paper No. 07-0360-W

Telematics – The Essential Cornerstone Of Global Vehicle And Traffic Safety

James Remfrey, Peter E. Rieth, Ulrich Stählin, *Continental Automotive Systems, Germany*

Abstract:

The networking of active and passive safety (APIA), is the fundamental basis for comprehensive vehicle safety. Situation-relevant information relating to driver reactions, vehicle behavior and traffic environment are fed into a crash probability calculator, which continually assesses the current crash risk and intervenes when necessary with appropriate measures to avoid a crash and reduce potential injuries. APIA provides effective protection not only for vehicle occupants but also for other, vulnerable road users. As this functionality up till now only relates to the vehicle itself, the next logical step is enhancement leading to the ultimate goal in safety performance, telematics. The integration of this embedded, in-vehicle wireless communication system allows Car-to-Car (C2C) and Car-to-Infrastructure (C2I) functionality for, e.g. hazard warning. This is an integral element of the cascaded Active/Passive Integration Approach.

This paper describes the current status in the functional potential attained by networking active and passive safety systems (APIA) and introduces the next ultimate step towards global vehicle and traffic safety, telematics.

Paper No. 07-0448-W

Project: Black Box

Jiøí Plíhal, *e4t Electronics For Transportation s.r.o.*

Martin Pípa, *Transport Research Centre, Czech Republic*

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Abstract:
The project Black Box is solved in the frame of the national R&D program for the Czech Ministry of Transport. The name of project is derived from the "black box" data recorders used in airplane cockpits. Black Box (Event Data Recorder) collect, record, store and export data related to motor vehicle pre-defined events. In this project we have designed black box that collect all relevant data mainly from vehicle control units trough CAN-BUS. In the black box are GPS and GSM modules included also. The part of project solution is the relevant legislative suggestion as well.
Project goals are to:

- Create an instrument for support clearing up specific road traffic accidents (chain accidents, etc.)
- Simplify the guilty and innocence clarification
- Make easier the process liquidation of insurance events
- Increase the active safety (psychological subconscious of driver about the chance to documentation behaviour of vehicle)
- Support the process of legislation to integrate the system in vehicles

Paper No. 07-0451-W

Enhancing Future Automotive Safety With Plastics

Michael Fisher, James Kolb, *American Plastics Council/American Chemistry Council*
Suzanne Cole, *Cole & Associates, Inc., United States*

Abstract:
A revolution in automotive technology is underway globally. Automobiles of the 21st century will feature radically improved safety and sustainability attributes. Safety R&D is embracing active and passive systems, and advanced vehicle propulsion R&D is tackling cleaner, more reliable energy sources. The innovations under development across multiple transportation venues including aerospace have the potential to alter automotive vehicle designs and supporting infrastructures globally by 2025.

These revolutionary changes suggest a critical need to rethink vehicle architecture and materials requirements. Versatile, durable, and lightweight plastics, plastic composites and plastic-metal hybrid materials that increase the efficiency, crashworthiness, and functionality of today's vehicles hold immense potential to radically enable and optimize advanced vehicle technologies for the future. An important step was taken in this direction in 2002 when the American Plastics Council (APC) published Plastics in Automotive Markets—Vision and Technology Roadmap to help define this potential.

Recognizing this need APC sponsored a Technology Integration Workshop in 2005 to explore the full potential of polymer-based materials to enhance next-generation systems (passive and active) for superior automotive safety. The National Highway Traffic Safety Administration (NHTSA) Office of Vehicle Safety Research contributed its expertise to the process. R&D priorities were explored in four automotive areas (Interiors, Body/Exterior, Powertrain & Chassis, Lightweighting).

Technical Session: Active/Passive Safety: Applying Integrated Solutions Along The Crash Timeline

The Technology Integration Report provides a baseline for a more expansive safety roadmapping effort that will reflect the consensus of leading technology developers, polymer and composite researchers, automotive safety engineers, designers, manufacturers, and government. This collaborative approach will also help industry, academia, and the government labs identify opportunities for new partnerships to pursue specific technologies or opportunities and will aid NHTSA in coordinating R&D and leveraging resources.

This paper will explore the role of the Plastics Industry in development of Future Vehicle Architectures with enhanced active and passive systems for improved automotive safety worldwide.

Technical Session: Active/Passive Safety: Applying Integrated Solutions Along The Crash Timeline

Technical Session: Vehicle Handling Stability and Control Systems and Rollover Prevention

Paper No. 07-0334-W

Performance Of An Improved ABS And Expected Safety Benefits

Fenaux Eric, Blaise Philippe, *PSA Peugeot Citroen, France*

Abstract:

ESC efficiency to reduce accident is now well proven. But ESC has a significant cost and install it as a standard equipment on small cars will make them more expensive and then slow down the modernisation of the car in the street which is the most efficient way to improve safety.

On the other hand ABS is already a standard equipment on all cars in many countries. Then if an ABS can significantly improve the stability of the cars in real world accident cases, one can expect major safety benefits without this cost problem.

As ABS can be efficient only when drivers brake, accident statistics obtained in France and studies of drivers' reactions are shown to establish in which cases the driver has an action on the brakes. Important cases like accident in a curve, in a straight line or at an intersection are addressed. It is shown that a significant accident reduction can be expected with an improved ABS.

We made measurements of car behaviour during tests reproducing such accident situations. Results of these measurements are produced to compare the stability of a car equipped with the sensors of a state of the art ESC and the improved ABS. As a reference performance of a car fitted with a current ABS are also provided.
The special algorithms of ABS used to obtain these improvements are introduced.

Paper No. 07-0353-W

Robustness Of Sideslip Estimation And Control Algorithms For Vehicle Chassis Control

Aleksander Hac, Edward Bedner, *Delphi Corporation, United States*

Abstract:

Accurate information about the vehicle sideslip angle or velocity is critical in controlling vehicle motion in the yaw plane using active chassis systems, such as brake based ESC (Electronic Stability Control) systems and active front or rear steering systems. Since the sideslip angle cannot be measured directly, it is estimated using available sensors and knowledge of vehicle dynamics. Consequently, the accuracy of estimates is affected by the sensor errors, unknown disturbances and the mismatch between the model and the actual vehicle. In order to maintain safe and consistent handling behavior of controlled vehicle, it is important to know the accuracy of the sideslip estimates in a variety of operating conditions and, if necessary, to modify the control algorithms in order to achieve sufficient robustness.

Technical Session: Vehicle Handling Stability and Control Systems and Rollover Prevention

In this paper a process of evaluating robustness of the sideslip angle estimation and control algorithms is described and selected results are presented. The estimation algorithm is a non-linear observer with parameter adaptation to road friction and a compensation for a road bank angle. The estimator relies on the information from the sensors and other estimates, on a nominal model of vehicle and assumptions about (lack of) disturbances, all of which may be inaccurate. In order to evaluate the effects of these errors on the estimation of sideslip angle, a systematic robustness study is performed. It uses analysis, simulations based on a validated vehicle model and vehicle testing. First, the effects of single factors in various maneuvers are examined and those having the largest contributions to errors are identified. Subsequently, the combinations of multiple error factors are studied, with the emphasis on the worst possible combinations. The robustness of the control algorithm is then evaluated along the same lines, with the particular emphasis on the worst case scenarios, when the sideslip angle estimates are the least accurate.

It was found that the largest single error-contributing factor was the bank angle of the road, especially when it was changing fast, while the effects of such factors as the presence of a trailer, or changes in tire cornering stiffness had relatively small effects. Consequently, modifications were made to the bank angle estimation and compensation algorithms and to vehicle control when large bank angles are detected.

Paper No. 07-0395-W

Demonstration Of Streamlined Initial Test Regime Utilizing The NHTSA NCAP Rollover Maneuver

Mark Arndt, *Transportation Safety Technologies Inc.*
Norma Hubele, *Arizona State University and Refrac Systems, United States*

Abstract:
An experiment was designed to evaluate the effect of changes to two vehicle parameters on rollover maneuvers. The changed parameters were tire size and static stability factor (SSF). The statistically designed experiment tested each vehicle condition utilizing the NCAP Dynamic Rollover Maneuver. Analysis of the test results showed revealed that for evaluation of effects in vehicle response due to changes of vehicle parameters no additional statistically significant information in vehicle response was observed for initial left turn versus initial right turn and default steer versus supplemental steer. When evaluating vehicle response to changed vehicle parameters an initial streamlined test regime utilizing the NCAP Rollover maneuver is suggested. A second statistically designed experiment utilizing the initial streamlined test regime examined the effect of changes to two vehicle parameters on rollover maneuvers. The changed parameters in this experiment were roll moment distribution and static stability factor (SSF). The complete NCAP Dynamic Rollover test procedure for vehicle validation is recommended. Future investigations that build on these results could include changes in the roll moment distribution together with SSF.

Paper No. 07-0496-W

NHTSA Tire Aging Test Development Project - Phase I Phoenix, Arizona Tire Study

James MacIsaac, *National Highway Traffic Safety Administration*

Technical Session: Vehicle Handling Stability and Control Systems and Rollover Prevention

Sebastien Feve, *Transportation Research Center, United States*

Abstract:
NHTSA knew from tire recall investigations that tires tend to fail at higher rates in areas with high average ambient temperatures and that these rates appeared to increase with the length of service (age) of the tire. So the question was: Can we quantify the degradation of tires in high temperature regions with time and use? What are the basic mechanisms of the degradation? Can these mechanisms be simulated for an accelerated aging test for tires?

Six different tire models were collected off of privately owned vehicles in the Phoenix, Arizona metropolitan area during the spring of 2003. Within the six different tire models studied, a total of 175 Phoenix-retrieved tires of varied ages and mileages were compared to 76 new, un-used versions of themselves in an assortment of tire component material tests or whole-tire roadwheel tests. The results of the laboratory and roadwheel tests were correlated against the tire's age (based on the date the tire was removed from the vehicle minus the date of production) and for original equipment tires their known mileage.

The study provides a basis to artificially age a new tire to the equivalent of a specific number of years in service. The artificially aged tire will be subjected to a test to evaluate its performance and durability as compared to a field tire with the same actual number of years in service.

The tires collected from service in Phoenix, Arizona displayed marked rate of degradation in material properties and whole tire performance that continued throughout the service life the tire.

This study is a comprehensive look at not only the mechanisms responsible for age-related tire degradation but also their implications on the load carrying and high speed capacity of the tire throughout the service life of a tire.

Technical Session: Vehicle Handling Stability and Control Systems and Rollover Prevention

Technical Session: Biomechanics: Tools Development

Paper No. 07-0151-W

Validation Of A Seat-Dummy Simulation Model For Rear-Impact

Thomas Deter, *IAT Ingenieurgesellschaft fuer Automobiltechnik mbH*
Axel Malczyk, Matthias Kuehn, *German Insurance Association, Germany*

Abstract:
Seat test standard protocols have been established by insurance research institutes (IIWPG) and consumer test organisations are developing similar test procedures to assess the performance of seats under rear-impact crash conditions.
With several numerical simulation models of the BioRID II being commercially available this study is intended to validate a multi-body rear-impact dummy model in a neutral seat environment for a range of seating postures and impact severities. This enables the systematic investigation of those parameters of the seat which influence the biomechanical loading on the dummy.
For this purpose, five sled tests were conducted on a newly developed test device that employs a stationary sled carrying the seat and dummy that is accelerated from the rear by a sled-on-sled impactor system. The BioRID dummy was placed on the so-called Chalmers seat which was developed in previous EU co-funded research projects and provides several adjustment possibilites to represent different seat shapes and characteristics. Starting with a medium severity crash pulse four additional validation tests were carried out with lower and higher crash severity as well as different seat and seating positions to cover a broader range of conditions.
Modelling involved both the detailed measuring and computational representation of the Chalmers seat as a multi-body model with facet surfaces as well as careful documentation of the placement of the BioRID model on the seat.
Based on the comparison of the model response with the kinematics and biomechanical measurements from the basic test an acceptable conformity between numerical model and validation test could be found for most body regions. However, some shortcomings in the dummy model were identified. A comparative representation of the major loadings measured in test and numerical simulation is given.

Paper No. 07-0228-W

Evaluation Of The 95th Percentile Hybrid III Large Male Dummy

Joshua Shaw, *Transportation Research Center Inc.*
Edward Probst, Bruce Donnelly, *National Highway Traffic Safety Administration, United States*

Abstract:
Research question: Does the Hybrid III 95th percentile large male dummy meet historical NHTSA standards for reproducibility, repeatability, and durability?

Methods: Drawing package review activities are detailed along with actual dummy inspection results. Certification tests and high energy tests, to assess reasonable durability, were completed on two dummies from different manufacturers. Response data from multiple repeats of the proposed SAE calibration and inspection test procedures (SAE Engineering Aid 26) are used as the basis for

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comparison. An overview of the test methodologies employed is presented as well as a statistical comparison of the response results from the two dummies. The process detailed by Rhule et. al. (ESV 2005) is utilized to ensure that the proper steps are completed for the evaluation and documentation of the activities conducted to evaluate the dummy for possible future Federalization.

Data sources: Six repeats of each certification test are completed on each dummy and/or component. High energy test levels are based on vehicle crash data at NCAP velocities to ascertain an upper limit of acceptable performance.

Expected Results: The expectation of this study is that the 95th percentile dummy will meet historical NHTSA standards for repeatability, reproducibility, and durability as required for incorporation into Part 572 of the Code of Federal Regulations.

Conclusions: The process described by Rhule et al. and employed in this study is a useful tool along the path of dummy Federalization.

Discussion: Dummy response performance is discussed with respect to the certification procedures with a focus on repeatability, reproducibility, and durability. The utility of the process detailed by Rhule et. al. is also examined and discussed.

Limitation of study: Only two dummies are tested, one from Denton ATD and one from First Technology Safety Systems. In addition only six repeats of the certification tests are completed for each component.

What does the paper offer that is new in the field? This paper offers documentation of the process performed to assist in the determination of the suitability of the HIII-95m for possible future inclusion into Part 572.

Paper No. 07-0458-W

Effect Of Muscle Contraction On Knee Loading For A Standing Pedestrian In Lateral Impacts

Anurag Soni, Anoop Chawla, Sudipto Mukherjee, *Indian Institute of Technology, Delhi*
India

Abstract:
Knee injury thresholds are based on cadaver experiments and do not take into account active muscle contributions. Preliminary studies have indicated that muscle forces reduce injury risk in knee ligaments [Soni et al, 2006]. In this paper we study the effect of active muscle forces on knee bending angle and shear displacements for a free standing pedestrian in lateral impacts using PAM-CRASHTM.
A passive FE model has been developed and validated for tests reported in Kajzer et al. (1997, 1999) and Kerrigen et al. (2003). An Active Lower Extremity Model for Safety (A-LEMS) has then been developed by including forty seven lower extremity muscles. A-LEMS has then been used to simulate below knee and ankle impacts in free standing pedestrians with activated and deactivated muscles.
The FE model shows good correlation with both Kajzer's and Kerrigan's tests results. On incorporating active muscles, it is observed that ligament strains decrease, even though the Von Mises stresses in the

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bones do not show a significant difference. Knee bending angle and shear displacement curves also show lower peaks with active muscles.

We conclude that muscle activation reduces ligament strains, as well as knee bending angles and shear displacements. It suggests that knee injury thresholds can be different from those formulated on the basis of cadaver studies. Therefore muscle effects should be taken into account in deciding vehicle safety standards and injury predictions in pedestrian crashes.

In this study we have assumed a straight line of action for muscles. This can lead to errors for muscles which do not work along a straight line. Tendons should also been included for more accurate muscle modeling. Currently, the study is also limited to the standing posture only and other postures are being investigated.

The current study investigates the effect of active muscle forces on the knee injury thresholds for a standing pedestrian.

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Technical Session: Advanced Technology Human Performance

Paper No. 07-0139-W

An Empirically Based Process For Estimating Safety Benefits Of Pre-Production Systems

August Burgett, Gowrishankar Srinivasan, Raja Ranganathan, *URC Enterprises, Inc., United States*

Abstract:

An Empirically Based Process for Estimating Safety Benefits of Pre-production Systems

The advent of new crash prevention technologies has made it necessary to develop new methodologies capable of estimating safety benefits of technologies before they are introduced into the market. This paper describes the development of one such empirically based methodology for estimating safety benefits.

The methodology uses a detailed engineering description of the crash prevention system performance in conjunction with a universal description of crash casual factors and resulting relevant crash types. This study also establishes objective tests to evaluate systems; a brake assist system is used to describe the process.

Crash data files GES and FARS are used to develop Measures of Performance (MOP) and are used as the basis for objective tests. Naturalistic driving data are used to estimate Exposure Ratio and to refine elements of the objective tests. Finally, data from the objective tests are used to estimate safety benefits of the crash prevention system.

The process developed here has not been applied to a specific system. For that reason, a hypothetical generic brake assist system is used as an example to demonstrate the data processing required to convert test outcomes to number of crashes that would be prevented. This hypothetical example suggests that such a system could prevent 50% of rear-end-crashes in which the following vehicle brakes to avoid crashing into a decelerating lead vehicle.

This new process has not been applied at this time. Challenges that will arise during application of these procedures are not addressed in detail in this paper.

Paper No. 07-0170-W

The Study On The Influence Of Audio Warning Systems On Driving Performance Using A Driving Simulator

Shun-Hui Chang, Jiun-Ren Hwang, *National Central University*
Chun-Chia Hsu, *Lunghwa University of Science and Technology*
Chin-Ping Fung, *Chung Cheng Institute of Technology*
Wen-Jing Chou, Kai-Kuo Chang, *Ministry of Transportation and Communications, Taiwan*

Abstract:

The traffic accident has been one of the first ten death factors in Taiwan for past years. The published statistical data showed that the number of casualties has gradually increased, and indicated that the main cause of traffic accident was the negligence by drivers, nearly twenty percent of the total amount of accidents every year in Taiwan. Many published researches about driving safety pointed out that the

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negligence is usually caused by driver¡¦s distraction and low level of alertness. In recent year, the Collision Warning System (CWS) providing visual, tactile and various audio signals to stimulate the driver¡¦s sense of hearing for warning purpose has been developed to assist drivers for a safe driving. Therefore, this study investigated the effect of various audio signals in the collision warning system on driving performance using a driving simulator. The driving performances in perception-reaction time, speed and lane position deviation were recorded. In this study the driver encountered a sudden cut-in of an event vehicle from an adjacent lane, braking in front and speeding up. The design levels were no alert, speech and beep sound in the collision warning system. Thirty male participants ranging from 20 to 30 years of age were recruited. The experimental results showed that a car with warning system could make the driver be on alert earlier and thus reduce the perception-reaction time. In addition, the beep sound induced a shorter perception-reaction time than the speech did. The driver would reduce speed when the vehicle equipped with warning system. With respect to the amount of lane-departure, the data showed that the position deviation was small as the driver did not change lane when the emergence happened in front.

Paper No. 07-0238-W

Development Of A Performance Specification For Indirect Visibility Systems On Heavy Vehicles

Paul Rau, *National Highway Traffic Safety Administration*
Richard Hanowski, Walter W. Wierwille, William A. Schaudt, Santosh Gupta, *Virginia Tech Transportation Institute, United States*

Abstract:
Recent advances in video technology and image processing have heightened the prospect for improving commercial vehicle safety by enhancing the ability of the driver to perceive and respond safely to surrounding traffic. This paper describes the experimental method and results of a novel approach used to measure the quality and quantity of field of view in a static environment, and then the experimental method of an approach for implementing and testing those requirements using drivers performing maneuvers on a test track course. Various configurations of camera placement, camera optical characteristics, and image viewing surfaces have been implemented for this research. These studies are presently underway, with completion expected by April 2007. The purpose of this paper, therefore, is to disclose the experimental methodology and research protocols that will be implemented to develop the performance specifications for these indirect viewing systems. This research proves the foundation for developing enhancements of the video imagery in order to implement an all-weather/360 degree indirect viewing system for commercial drivers.

Paper No. 07-0433-W

A New Markovian Model To Categorize Driving Situation

Dapzol Nicolas, Tattegrain-Veste Helene, *LESCOT/INRETS*
Ciuperca Gabriela, *LAPCS, France*

Technical Session: Advanced Technology Human Performance

Abstract:
One of the ways to improve the effectiveness of current driver assistance systems is to adapt their assistance according to each specific driving situation. A driving situation can be defined as the environment around the driver and his objective in this particular environment. To analyse and categorize these two factors, we choose to model the evolution of the data collected by the vehicle sensors.

To achieve this purpose, we propose a new modelling. The goal of this modelling is to analyze the evolution of sensors data regarding the different situations encountered by drivers.

This new modelling adds a weight feature to the classic Semi Hidden Markov Model framework.

To assess its sturdiness, we conduct an experiment in real environment which allows us to record 718 various driving sequences.

The modelling is implemented using 20% of these sequences. On the remaining sequences, our modelling hypothesis allows us to categorize driving situations with a 85% success rate.

These results show the effectiveness of this type of approach to understand and to predict driving situations.

Paper No. 07-0434-W

To Be Available Or Not, That Is The Question: A Pragmatic Approach To Avoid Drivers Overload And Manage In-Vehicle Information

Thierry Bellet, Julie Manzano*, Institut National de Recherche sur les Transports et leur Sécurité, France*

Abstract:
This research takes place in the AIDE project , and is an extension of the INRETS-LESCOT previous work done in CEMVOCAS project. Synthetically, LESCOT objective in AIDE is to design and develop a Drivers Availability Estimator module (DAE) in charge to assess drivers' ability to receive and process information while driving. This module has to manage the information intended to the driver in an adaptive way, according to the requirements of the current driving task and the availability of the driver. Availability is a user centred concept defined at LESCOT in order to "translate" the question of "Driving Demand" in a pragmatic approach: if the driving demand is high, driver's attention must be focused on the driving task and, consequently, s/he is not available to do another task. On the contrary, the driver is potentially available when the driving demand is low.

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This paper will present the methodology carried out and the data collected for the DAE design and development. In order to study drivers' availability, an experiment has been implemented in real driving conditions. For this study, 30 drivers have participated. They had to drive an experimental car and to follow the route given by a guidance system. They also had to describe or repeat visual (pictograms or texts) and auditory information displayed by a home made device introduced on the car. During the driving phase, objective parameters (like drivers' action on pedals) and video films of the road scene were collected. After driving, participants were interviewed in order to collect their opinion concerning the message impact on the primary driving task (according to several dimensions, like disturbance effect, or self-assessment of their driving performance).

This paper will present at first the method used, the data collected and the main results obtained. Then, it will discuss the concept of "availability" (i.e. message acceptance) according to the driving conditions (current road infrastructure, goal followed, driving action carried out and event occurrences) and the consequences for the DAE design and real time information management to avoid drivers overload.

Technical Session: Advanced Technology Human Performance

Technical Session: Compatibility in Frontal/Side Collisions

Paper No. 07-0188-W

Finite Element Analysis Of Compatibility In Frontal Collisions

Pradeep Mohan, *George Washington University*
David Smith, *National Highway Traffic Safety Administration, United States*

Abstract:
Several numeric measures have been proposed to assess crash compatibility between two vehicles. The measures under investigation in this study are the Average Height of Force 400 (AHOF400) and the Crush-Work Stiffness 400 (Kw400), both measured in 35 mph full-frontal rigid barrier tests. AHOF400 is a measure of the vertical centroid of forces exerted on the barrier surface for the first 400 mm of crush. Kw400 is a measure of the work required to crush 400 mm of the vehicle's front end. The paper presents an analysis of the error in AHOF400, the dependence of Kw400 on vehicle weight, the use of the metrics to match vehicles, and injury results in vehicle-vehicle simulations where AHOF400 is varied.

Several studies in the past have concluded that there are large inherent errors in the AHOF measure. One of the main factors influencing the error in this measure is the size of the load cell on the barrier face. In this study, the error bounds in AHOF as a function of barrier load cell size are computed using computer simulations and recommendations for barrier improvement are offered.

Due to the errors associated with the AHOF measure, the relationship between occupant injury measures and height of force matching in the light vehicle crash data is not well understood. In this study, a matrix of vehicle-to-vehicle simulations is conducted by varying the front-end geometric alignment between the target and bullet vehicle. The intrusion and acceleration pulse from the target vehicle are used to predict injury measures for a belted 50th percentile Hybrid III dummy in the driver position. This research will enable us to better understand the effects of height of force matching in the vehicle fleet.

Paper No. 07-0347-W

Front-To-Side Crash Compatibility Analysis Using A CAE Based Methodology

Saeed Barbat, Xiaowei Li, Priya Prasad, *Ford Motor Company, United States*

Abstract:
Fundamental physics and numerous field studies have clearly shown a higher fatality risk for occupants in smaller and lighter vehicles when colliding with heavier ones. The consensus is that the significant parameters influencing compatibility in front-to-side crashes are geometric interaction, vehicle stiffness, and vehicle mass. The effect of each individual parameter on the outcome of occupant responses in the light vehicle, however, is not clearly understood. A finite element (FE) model based design of experiments methodology focused on discerning the effects of a few design variables on dummy responses in front-to-side vehicle crash was developed. This study utilized a deterministic approach including optimally spaced Latin hypercube sampling which allowed analytical prediction equations for

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dummy responses to be generated from twenty-one simulation runs. Selected response variables were the dummy injury measures thoracic trauma index (TTI) and pelvis acceleration. Several multi-dimensional response surfaces were constructed based on the simulation results and found to be well correlated (R2= 0.82 and R2=0.93 for TTI and pelvis acceleration, respectively). These response surfaces were then used to determine prediction equations as functions of vehicle design variables that were verified using additional simulations. Results indicate that geometric interaction and lowering front-end structures in vehicle-to-vehicle front-to-side collisions have the greatest effect on reducing (struck vehicle driver) TTI than other design variables. This was found to contrast the pelvic acceleration results, which tended to increase with lowering front-end structure height of the impacting (strike) vehicle.

Paper No. 07-0391-W

Research On Possible Car To SUV Compatibility Evaluation Method

Koichi Sagawa, Nobuhiko Takahashi, Shinkichi Toyosaki, Hayata Uwai, *Nissan Motor Co. LTD, Japan*

Abstract:

The method to evaluate vehicle compatibility has been studied for this 10 years by crash safety experts in the world. This reports the issues on possible technical requirement of geometry and stiffness matching, which are called as AHOF400 and KW400. Research performed on Car to SUV tests and barrier tests shows following concerns:

1. Issue on interaction: In order to get AHOF400 of SUV to be around passenger car's front longitudinal main structure height, SUV's longitudinal might be needed to be lower than Passenger's, due to the vehicle (bonnet) height.
2. Issue on stiffness: KW400 depends on front end packaging, for example longer space in bumper fascia reduces KW400 lower but it should not improve real world car to SUV stiffness matching.
3. Issue on stiffness: Stiffness have to have some dependence with Vehicle mass, so perfect stiffness matching might not be realistic. Scope should be clarified.

Technical Session: Compatibility in Frontal/Side Collisions

Technical Session: Rear Impact Injury Prevention

Paper No. 07-0199-W

Development Of Computer Simulation Method For Seat Optimization To Reduce Neck Injury In A Low Speed Rear Impact

Sung-Chul Choi, Sung-Jun Han, Han-II Bae, Si-Yeol Kim, *Hyundai Motor Company, Republic of Korea*

Abstract:

The objective in our study is to increase our understanding of the design parameters for seat and active headrest performance in relation to the rear-end collisions and to examine how the dummy position (including the height) affects the injury values. We performed a study to seek the optimized seat characteristics with BioRID II dummy (made by TNO) and MADYMO software.

Technical Session: Rear Impact Injury Prevention

Technical Session: Improved Safety For Pedestrians and Other Vulnerable Road Users

Paper No. 07-0126-W

WATCH-OVER – The Concept Of A Cooperative System For Vehicle To Vulnerable Road Users Communication

Katrin Meinken, *University of Stuttgart*
Axel Sikora, *Steinbeis Research Institute Wireless Communications, Germany*
Luisa Andreone, Andrea Guarise, *Centro Ricerche Fiat, Italy*

Abstract:
The main goal of the WATCH-OVER project is to avoid road accidents that involve vulnerable road users such as pedestrians, cyclists and motorcyclists. The innovative concept is represented by an on-board platform and by a vulnerable user device. The system concept is based on the interaction between an in-vehicle module and users' devices.

The project carries out research and development activities aimed to design and develop a system for accident prevention involving vulnerable users in urban and extra-urban areas.
The main activities include:

- Identification of user requirements and relevant use cases.
- Specification of system architecture, functions and applications.
- Selection and adaptation of the most promising short range communication technologies.
- Design and development of the system customised for different users.

WATCH-OVER intends to examine the detection of vulnerable road users in the complexity of traffic scenarios in which pedestrians, cyclists and motorcyclists are walking or moving together with cars and other vehicles. The technological challenge is the development of a cooperative system for real time detection and relative localisation of vulnerable road users that includes innovative short range communication and video sensing technologies. The implementation challenge is the deployment of a reliable system that is versatile for different vehicles and vulnerable road users.
The system is limited to urban and extra-urban areas only, so traffic situation on motorways or high speed scenarios are not considered in this project.

Paper No. 07-0179-W

Computer Simulation Models For Developing A Biofidelic Flexible Pedestrian Legform Impactor GT (Flex-GT)

Takahiro Issiki, Atsuhiro Konosu, *Japan Automobile Research Institute*
Masaaki Tanahashi, *Japan Automobile Manufacturers Association, Inc., Japan*

Abstract:
The Japan Automobile Research Institute and the Japan Automobile Manufacturers Association, Inc., have been developing a biofidelic flexible pedestrian legform impactor (Flex-PLI) since 2002. Flex-PLI

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has flexible long bones like human bones and is equipped with many sensors to evaluate the severity of pedestrian lower extremity injuries in multiple locations.

In this study, we develop computer simulation models for developing a biofidelic flexible pedestrian legform impactor GT (Flex-GT).

This paper presents detailed information on the computer simulation models and numerous validation results for the models.

Paper No. 07-0196-W

Concept Design Of A 4-DOF Pedestrian Legform

Qing Zhou, Huiliang Du, *Tsinghua University, Peoples Republic of China*
Michael Quade, *RWTH-Aachen, Germany*

Abstract:
The new car-to-pedestrian impact safety protection regulation in Europe has prompted many research efforts in this area. For knee and lower leg protection, the current regulation requires using a legform that consists of two degrees-of-freedom for injury assessment It mimics the shear and bending about the knee joint when a pedestrian impacted by a vehicle from the side. However, the 2-DOF legform cannot assess non-lateral impact accidents. Besides, even the impact is 100% lateral, once the legform contacts with the bumper, it could rotate towards the other directions due to the curvatures of the bumper shape and the deformation of the bumper foam.

In this paper, a concept design of a 4-DOF pedestrian legform is documented. The two added DOF represent the natural human knee rotation and the shear about the knee joint when a pedestrian is impacted from the front or the back. In fact, these two DOF already exist in the Hybrid III dummy knee for assessing femur and knee injuries using the Hybrid III dummy sitting in a car involved in frontal impact. Therefore, the new 4-DOF legform is a combination of the current 2-DOF pedestrian legform and the Hybrid III dummy knee, from which the joint stiffness data are also adopted. The challenge is to design all the 4-DOF mechanisms, including the motion and stiffness mechanisms, in a limited space. The goal of the project is to develop a pedestrian legform that can assess injuries from omni-direction impact. It remains to be studied if superimposing the joint stiffness of different directions makes sense in biofidelity.

Paper No. 07-0267-W

Stiffness Corridors Of The European Vehicles For Pedestrian Simulations

Luis Martinez, Luis Guerra, Gustavo Ferichola, Antonio Garcia, *UPM-INSIA, Spain*
Jikuang Yang, *Chalmers University, Sweden*

Technical Session: Improved Safety For Pedestrians and Other Vulnerable Road Users

Abstract:
Multibody simulations of pedestrian impact scenarios as well as pedestrian accident reconstructions have been used and improved through the years to enhance the pedestrian protection.
In these years, pedestrian multibody models have been developed and validated extensively but there has not been a uniform approach to the pedestrian-vehicle contact interactions. In general, the reference values used for the stiffnesses of the impacted cars were individually obtained for each car through testing or through FEM simulations.
This paper defines and supplies to the research community appropriate and wide test based estimates of the stiffnesses of the European vehicles front parts for pedestrian simulations. They consist of a set of stiffness corridors based on the pedestrian subsystem tests from EuroNCAP.
Based on the 425 tests that EuroNCAP has made available for APROSYS SP3 sub-project, this paper defines procedures to derive the vehicle stiffness out of these pedestrian tests, applies them extensively to these 425 tests and builds a set of stiffness corridors for the different vehicle front parts areas.
This paper presents the result of this process: five set of corridors for the car bumper, bonnet and windscreen base that represents the different European car segments.
Moreover, some guidelines are included in the paper to apply appropriately the obtained corridors for pedestrian simulations with the different current European vehicles.

Paper No. 07-0307-W

Technical Solutions For Enhancing The Pedestrian Protection

Richard Zeitouni, Christian Pinecki, *PSA Peugeot Citroën, France*

Abstract:
Since October 2005, the European regulation for pedestrian protection is applicable to new vehicles. Four impactors have been developed: leg, femur, child and adult heads for testing predefined areas on the front face of the vehicle.
This paper presents the technical strategy and the set of solutions which place PSA as one of the best manufacturers for pedestrian protection with in particular Citroën C6, first and unique vehicle achieving 4 stars in EuroNCAP pedestrian protection assessment.
The scenario of head and leg protection is articulated around two requirements:

- keeping a space between the bonnet and the various hard elements of the engine, and behind the front bumper so that the impactors do not come into contact with rigid elements,
- softening the bonnet and the front bumper elements in order to generate a more progressive head and leg deceleration during the impact.

The level of constraint induced by these requirements penalizes heavily the style and the overhang of the vehicles. Massive development efforts have been invested in both fields of leg and head protection. The physical characteristics of the components and the design constraints have to be optimized under advanced computational analyses with finite elements model.
The protection of the leg requires the installation of two absorbers (upper and lower)

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The head protection requires complex tuning of the stiffness of the bonnet and some components inside the engine compartment. For executive cars with long hood, like C6, it also implied the development of an active bonnet, triggered by fusible optic sensors, which is not only a technical challenge but also addresses outstanding issues in the field of quality and reliability.

The paper provides technical descriptions of the methods deployed by PSA, associating numerical simulations and physical tests, for developing innovative solutions in the field of passive and active safety.

Paper No. 07-0373-W

Pedestrian Head Impact - What Determines The Likelihood And Wrap Around Distance?

B. Johan Ivarsson, Jeff R. Crandall, *University of Virginia*
Christine Burke, Samir Fakhry**,** Jurek Grabowski, Greg Stadter, *Honda INOVA Fairfax Hospital CIREN Center, United States*
Rikard Fredriksson, *Autoliv Research, Sweden*
Matthias Nentwich, *Autoliv GmbH, Germany*

Abstract:
Research question/objective: While reconstruction of vehicle-pedestrian crashes typically uses the pedestrian stature as an estimate of wrap around distance, laboratory investigations with cadavers and dummies have shown that numerous factors determine the likelihood and location of initial head contact. The current field data study evaluates the ability of vehicle and pedestrian parameters to predict the wrap around distance to head contact.

Data sources: Detailed information on 386 frontal pedestrian crashes in which the striking vehicle was either a car, pick-up truck, or an SUV was obtained from the Pedestrian Crash Data Study (PCDS) and Crash Injury Research and Engineering Network (CIREN) databases. Impact speed, pedestrian anthropometry, and vehicle front-end geometry were primary variables of interest.

Methods: Logistic regression was used to evaluate the importance of factors that determine the likelihood of head contact and sliding prior to head contact. Multiple regression was used to derive a model for predicting the wrap around distance to head contact.

Results and Discussion: As expected, the likelihood of head-vehicle contact increased with increasing impact speed and decreased with increasing hood height. The likelihood of sliding prior to head contact increased with increasing impact speed and was significantly higher ($p<0.05$) in cases for which the hip height to hood height ratio exceeded the value 1 than in cases in which the corresponding ratio was less than 1. Analyses indicated that the wrap around distance to head contact can be roughly estimated by a function of impact speed, pedestrian stature, and hood height.

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Conclusions: The results should facilitate evaluating the risk of head-vehicle contact in pedestrian crashes. In addition, the results can aid in the selection of critical regions for pedestrian head contact testing during countermeasure evaluations.

Limitation of the study: The relatively low sample size.

What does the paper offer that is new in the field:
Field based evaluations of the important factors for determining the likelihood and wrap around distance of pedestrian head contact with a striking vehicle.

Paper No. 07-0428-W

Pedestrian-Vehicle Accident: Analysis Of 4 Full Scale Tests With PMHS

Catherine Masson, Thierry Serre, Dominique Cesari, *INRETS, France*

Abstract:
In industrialized nations, more than 25% of road traffic fatalities concern pedestrians. In some large urban areas, pedestrians account for as much as 40 to 50 percent of traffic casualties. To investigate pedestrian impact requirements for regulation in Europe, four full-scale pedestrian impact experiments were performed on embalmed PMHS. Two impacts were conducted in a standard condition with the PMHS laterally at the center line of the vehicle with the struck-side limb positioned anteriorly. The 2 other tests were a reconstruction of two real accidents and the PMHS were hit by the vehicle front laterally from ¾ right. Each PMHS was instrumented to measure the acceleration at points along the lower limb, the pelvis, the head. Pedestrian height being an important factor in the type of injuries sustained, the vehicle profile in relation to pedestrian height was recorded. After each test, a necropsy of each PMHS revealed the injuries to the tested PMHS. The distribution of vehicle contact areas and throw distance were noted. Because the head and lower limbs are the most commonly injured body parts for adult pedestrians, with head injury being the main cause of fatality, the analysis was focussed on these two body parts. The kinematic response of the pedestrian surrogates head was measured using precisely located targets. In particular, head velocity and head impact angle on the windscreen have at the instant of the impact been evaluated. The results provide complementary data for future pedestrian test methods and biofidelity assessment of a pedestrian dummy.

Paper No. 07-0440-W

Pedestrians And Their Survivability At Different Impact Speeds

Richard Cuerden, David Richards, *TRL Limited*
Julian Hill, *Loughborough University, United Kingdom*

Technical Session: Improved Safety For Pedestrians and Other Vulnerable Road Users

Abstract:
The UK's On The Spot (OTS) accident data collection project started in 2000 and continues to investigate 500 crashes per year. Investigations are undertaken minutes after the collision has occurred to gather all the perishable information. At the time of writing over 3,000 crashes involving all road users and all injury severities have been examined. The OTS database provides a unique insight into the prevailing factors that have been seen to cause crashes and the associated human injuries and vehicle and infrastructure damage that have been witnessed by the crash investigation teams.
The research objective of this paper is to outline the pre and post-crash circumstances of 205 pedestrian crashes. The nature of the events that led to the collision, including the respective travelling speeds, time and distance from the moment the impact was inevitable are described. The information provided can be used to begin to outline the potential effectiveness of future crash mitigation systems. Further, the impact speeds are correlated to the injuries the pedestrians suffered with respect to the impact partner. Lower limb and head injuries are highlighted to be the most frequently injured body regions. The risk of injury for 175 pedestrians with respect to the cars' speed at the point of impact is outlined and comparison made with the literature.
The small sample size is a limitation to the work, which has not at this stage been proven to be representative of the UK pedestrian accident population. Further, the nature of real world crash investigation means that some of the calculated speed values have reasonably large ranges. However, the work does offer an up to date review of the risk and type of injury versus impact speed for modern vehicles. In addition, the study starts to describe the in-depth pre-crash circumstances witnessed in real life crashes.

Paper No. 07-0449-W

Active Pedestrian Head Protection Against Windscreen Impact

Caroline Deck, Violaine Tinard, Nicolas Bourdet, Remy Willinger, *University Strasbourg, France*

Abstract:
Research question and objectives: Recent in deep accident analysis demonstrates that the windscreen and pillars are very often involved in case of severe pedestrian head injury. The present study proposes an active protection system for pedestrian or cyclist head impact against the windscreen or pillar area.

Methods: In case of an automotive impact with a pedestrian, transducers record the impact and transfer the information to actuators which open the bonnet and eject a dampened flexible protective panel over the windscreen and pillars. This active protection system prevents the pedestrian's head to come into contact with the windscreen or pillar. In addition to the active treatment of the windscreen area a passive dampening of the bonnet is also provided.

Data sources: The problem related to pedestrian head impact against the car windscreen area has been well documented in the pedestrian accident investigation report provided by APROSYS project.
The head model and injury criteria used were those published by the University of Strasbourg.

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Results: In a first step, the multi body simulation showed that an activation of the protective panel within 100 ms and remaining until 250 ms is appropriate to avoid direct head contact with the windscreen or pillar. The multi layered flexible protective plate as well as the bonnet itself has then been optimised in terms of layer thickness, elasto-plastic and failure properties against both, HIC value and new biomechanical head injury criteria for adults and children.

Conclusions and discussion: In this numerical study the feasibility of an active and passive pedestrian head protection system has been illustrated. The time scale of an active panel, covering the windscreen and pillar, has been defined.

Limitation of the study: The study, is limited to the simulation of a new protective concept, with out any prototype. An experimental approach has to be conducted in order to validate the material and activation.

What does the paper offer that is new in he field
The paper presents an active protection device against pedestrian head-windscreen impact. A detailed numerical analysis enabled it to demonstrate the efficiency of this concept.

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Technical Session: Biomechanics: Injury Criteria and Test Procedures

Paper No. 07-0077-W

A Finite Element Modelling Investigation Of Lower Leg Injuries

Mike Neale, Régis Thomas, Helen Bateman, David Hynd, *TRL Limited, United Kingdom*

Abstract:

Injuries to the foot and ankle are typically not life threatening, but can lead to long-term medical complications and permanent disability. This paper details a programme of numerical simulation work that has been carried out to extend the understanding of foot and ankle injury mechanisms in frontal impacts.

The work involved the development of a detailed finite element model of the human lower leg, which explicitly represents the bones and the principal articulations and ligaments of the lower leg. Work has also been carried out to develop best practices for modelling the ankle and lower leg, including the importance that correctly simulating the articular surfaces and ligament tone has on the model's predictions.

Predictions from the model have been verified against three published sources of Post Mortem Human Surrogate (PMHS) test and injury-level data. The model provided adequate predictions of the PMHS results, which confirmed the biofidelic behaviour of the model.

Further to the model verification, the model has been applied to investigate the influence that environmental and subject variations have on predicted ankle injury risk. The environmental variations included model runs in which the loading through the foot and the orientation of the foot was altered. Subject variations included model runs in which the stiffness of the modelled ligaments was altered. Predictions from these model runs have been used to estimate whether existing PMHS foot and ankle injury datasets are likely to represent the most injurious loading conditions.

It is important to remember that care needs to be taken to understand how far the model may be used to extrapolate beyond physical test data. Nevertheless, this initial work provides useful information that could contribute towards the development of ankle injury criteria for advanced anthropometric test devices for assessing ankle injury risks in automotive impact tests.

Paper No. 07-0229-W

Theoretically Based, Statistically Justified, Thoracic Injury Criterion

J. Quinn Campbell, Rabih Tannous, *AASA Inc.*

Erik Takhounts, Peter Martin, Stephen Ridella, Rolf Eppinger (Retired), *National Highway Traffic Safety Administration*

Thuvan Nguyen, *On Point, United States*

Technical Session: Biomechanics: Injury Criteria and Test Procedures

Abstract:
As measurement capabilities in crash test dummies improve, new injury criteria must be developed to take advantage of these improvements. The THOR-NT dummy thorax has been designed with three-dimensional displacement measurement capability at four points in the chest. To correlate those measurements with injury, chestband displacements from Post-Mortem Human Subjects (PMHS) tests corresponding to the THOR-NT chest displacement points were used to simulate thorax loading in a 2-D finite element model of the PMHS thorax. The model, method and model validation were described in Campbell et al. (2005). In the current study, data from both upper and lower chestbands were used to predict rib fractures in the PMHS crash tests. Due to the close proximity of the two upper THOR-NT chest displacement points, some of the simulations did not adequately represent the PMHS loading. To improve the simulations, a new set of runs were created using wider chest displacement points to determine if they would be more successful in simulating injury. Rib stress and strain from the 2-D finite element model of the PMHS thorax were used to predict injury or non-injury in the PMHS tests. Statistical analysis using logistic regression was used to develop a new thoracic injury criterion based on the finite element model simulations.
Detail of Audience: Bioengineers, regulators, and safety system designers.

Paper No. 07-0289-W
Analysis Of NHTSA's THOR-NT Database
Peter Martin, *National Highway Traffic Safety Administration*
Lauren Shook, *GESAC, United States*

Abstract:
Since its release in 2005, NHTSA has collected data from over one hundred tests involving the THOR-NT advanced frontal impact dummy. These include sled tests, vehicle tests, and component tests of various speeds and configurations. This paper describes the purpose and findings of the various series of tests, and provides an analysis of the data that demonstrates the attributes of the dummy. Included among the tests are those aimed at establishing injury criteria for the head, thorax, cervical spine, and pelvis. New auxiliary tools, such as data processing software and computer models, are also described. Website links to THOR-NT data and reports are provided. This paper also summarizes some of the lessons learned from this broad test experience, and documents actions that are being taken to enhance dummy performance and acceptance by the international community.

Paper No. 07-0352-W
Biomechanical Differences In Contact And Non-Contact Head Impact In Vehicle Crash Tests
Jiangyue Zhang, Yabo Guan, Narayan Yoganandan, Frank Pintar, Thomas Gennarelli,
Medical College of Wisconsin, United States

Technical Session: Biomechanics: Injury Criteria and Test Procedures

Abstract:
The purpose of this research is to study brain biomechanics between contact and non-contact head impact during vehicle crash tests using SIMon finite element model. Acceleration data were extracted from 13 lateral and 14 rigid pole crash tests conducted by the US DOT NHTSA. Strain history at 4 locations, cumulative strain damage measure 15% (CSDM), dilatational damage measure (DDM), and relative motion damage measure (RMDM) were studied. Head contact occurred in two lateral tests and six rigid pole tests. Head contact duration were less than 1 ms in rigid pole tests and ranged from 3-7 ms in lateral impact tests. The ratio of biomechanical measurements between contact and no-contact cases in lateral tests were: translational acceleration 4x, rotational acceleration 3.5x, HIC 12x, peak strain levels 1.2-2.4x and CSDM 5x. The ratios were even higher for rigid pole tests: translational acceleration 14x, rotational acceleration 25.7x, HIC 29.5x, peak strain 3.3-4.4x, CSDM 12x. Results found peak strain levels, DDM and RMDM increases with the increase of rotational accelerations. They were lowest in no-head-contact rigid pole tests, followed by no-contact lateral impact test, contact lateral impact tests, and highest in head-contact rigid pole tests. CSDM also showed similar relation with rotational acceleration, except they were slightly higher in lateral tests than rigid pole tests for head-contact cases. The higher CSDM value indicated a more global involvement of the brain in head-contact lateral impact tests because peak strain levels were lower. On the other hand, translational acceleration magnitudes were correlated to HIC value but not correlated with the peak strain levels, CSDM, DDM and RMDM.

Paper No. 07-0357-W

A Rollover Human/Dummy Head/Neck Injury Criteria

Don Friedman, Carl Nash, *Center for Injury Research, United States*

Abstract:
The human neck is a remarkable device for its function, flexibility and strength. It supports the head while permitting a wide range of motion and sustains itself under some vigorous head impacts in violent sports and accidents. Nevertheless, the neck has limits both of motion and of the forces it can sustain. In rollovers, the neck is usually loaded through the top or back of the head with the torso providing an inertial reaction mass. Skull fractures, head and brain injuries generally involve higher impact velocities than are necessary to fracture the cervical spine, but which can also load and critically injure the neck.

Accident injury statistics, tests of living and post-mortem human subjects (PMHS), analysis of athletic impacts, tests of anthropometric dummies and computer simulations of human and dummy kinematics, illustrate injury mechanisms and suggest injury criteria measurements for the human neck. Using this data a simple vertical head impact measure as a neck injury criterion was developed to address the problem of neck injury in vehicle rollovers and to help identify appropriate vehicle design considerations for rollover occupant protection.

The analysis defines a head impact speed of 3 m/sec. (7 mph) which produces a neck load of 7,000 N in a 50th percentile male Hybrid III dummy, as the onset of serious neck injury, and that a head impact speed of 4.5 m/sec (10 mph) which produces a dummy neck load of 10,000 N represents the onset of

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severe to fatal neck injury. NHTSA has already accepted that a head impact velocity of 7 m/sec (16 mph) is the threshold for the onset of serious head and brain injury. These criteria are shown to reasonably represent available human injury accident and experimental statistical distributions.

Paper No. 07-0424-W

Comparison Of Tetrahedral And Hexahedral Meshes For Human Finite Element Modelling: An Application To Kidney Impact

Xavier Bourdin, Philippe Beillas, *Institut National de Recherche sur les Transports et leur Sécurité*
Philippe Petit, Xavier Troseille*, Laboratoire d'Accidentologie et de Biomécanique, France*

Abstract:
Hexahedral elements have been the solid elements of choice to represent solid organs in human finite element models for impact. While those elements are known to have advantages in terms of accuracy and computing cost, they are difficult to generate and meshing represents a significant part of the total developing time. The ever increasing level of anatomical details of current and future models further increases these meshing difficulties. In recent years, computing power has become affordable and the formulations of tetrahedral elements – that can be generated automatically even for complex shapes – have been improved.

The aim of this study was to evaluate the performance of two meshing approaches – hexahedron/semi-automatic meshing vs. tetrahedron/automatic meshing – for a biomechanical application.

In this study, the kidney was chosen because of its simple shape facilitating the hexahedral meshing. The model geometry was based on the detailed version of the Visible Human Project dataset. Five types of 3D solid elements (8 and 20 node bricks, degenerated 4 node tetrahedron, 4 and 10 node tetrahedrons) and two material laws (linear visco-elastic, hyper elastic viscous) were used to simulate a kidney impact described and simulated by Schmitt & Snedeker (2006).

The simulation results were compared in terms of computing cost, stability, force vs. displacement response and stress/strain patterns.
While the drawbacks of tetrahedral elements were observed in particular in terms of computing cost, the difference in model response was found to be acceptable in a biomechanical context where there are large uncertainties on material properties.
For more complex shapes, this increased computing cost may be largely outweighed by the advantages of an automatic meshing approach.

Paper No. 07-0475-W

Injuries To Occupants Of Recent Model Passenger Vehicles Involved In Frontal Crashes

Kennerly Digges, *George Washington University, United States*

Technical Session: Biomechanics: Injury Criteria and Test Procedures

Abstract:
By model year 2000, most manufacturers had the opportunity to modify air bags so they were less aggressive. As the air bags were modified, some vehicles also incorporated improved safety features into the safety belt system. It is of continuing interest to determine how these newer systems are performing and the characteristics of the injured population. This paper examines injuries in passenger vehicles, model year 2000 and later. NASS/CDS 2000 to 2004 was interrogated to determine distribution of injuries received by belted front seat occupants in frontal crashes by crash severity, occupant age, and injured body region.

Initially the fatalities of belted front seat occupants with known delta-V were examined. It was found that 63% of the fatalities were in extremely severe crashes. Extremely severe crashes were defined by a delta-V greater than 40 mph and/or occupant compartment intrusion greater than 18 inches. About half of the remaining fatalities, were in crashes with a delta-V less than 25 mph. About 60% of the fatalities in crashes less severe than 25 mph were occupants age 65 and older. These older occupants also accounted for about 62% of the fatalities in crashes less severe than 35 mph.

The distributions of MAIS 3+ injuries were examined by occupant age and crash severity. About 15% of the MAIS 3+ injured occupants were in extremely severe crashes. For the remaining group, about 78% of the injured were in crashes less severe than 25 mph. About one third of this injured group was younger than 35. Occupants older than 35 made up the vast majority of the MAIS 3+ injured occupants. Chest injuries accounted for the largest fraction of MAIS 3+ injuries at about 41%. Head injuries accounted for only 19% of the MAIS 3+ injured occupants.

The paper will also summarize the injuries to the unbelted population and will indicate promising opportunities for further safety improvements.

Paper No. 07-0503-W

Human/Dummy Rollover Falling (Excursion) Speeds

Don Friedman, Justin Caplinger, *Xprts LLC*
Jack Bish, *Consultant, United States*

Abstract:
Measurements of human and dummy falling (often referred to as diving) speeds were made from three series of experiments. The first series consisted of a 5th and 50th percentile human and a 50th percentile dummy in a production vehicle with production belts, in a spit test at roll rates to 200 degrees per second. The second series was conducted with surrogates in dynamic repeatable rollover test roof impacts in the Jordan Rollover System (JRS) fixture. The third series photo-analyzed dummy motion in the interior of dolly rollover tests with belted and unbelted hybrid III dummies to determine independently, the excursion and intrusion speeds of the dummy and roof.

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The first series measured the near and far side lateral and vertical excursion, excursion speed, roll rate, and belt loads, as well as, documenting occupant kinematics by lateral and frontal view video cameras. The second series measured the near and far side excursion and excursion velocity of a belted surrogate in 15 mph, 350 degree per second JRS roof impact tests. The third series photo analyzed high resolution video of dolly rollover tests with 50% hybrid III dummies, in addition to, the parameters collected in the tests associated with roll rate, dummy head impact speeds, and belt loads.

The measurements are presented in a graphical format with discussion in the context of rollover injury potential. The conclusions are that belted humans and dummies with 3 to 5 inches of excursion have excursion speeds of little more than 0.5 mph. The unbelted dummies, with a similar amount of initial headroom, have only slightly greater falling speed because of the short duration of the roof contact acceleration. Photo analysis of dolly rollover head impact speeds, as measured by dummy neck loads, separated the excursion and roof intrusion speeds and indicated similar falling speeds. An inch or more of intrusion from a roll caged roof, in combination with the close proximity of the head of a dummy, results in composite head impact speeds of 3 mph or more.

Paper No. 07-0512-W

Application Of ACN Data To Improve Vehicle Safety And Occupant Care

G. Bahouth, *Pacific Institute for Research and Evaluation*
J. Augenstien, E. Perdeck, K. Digges, J. Stratton, *University of Miami Miller School of Medicine, WLRIC*
P. Baur, G. Messner, *BMW, United States*

Abstract:
The introduction of Automatic Crash Notification (ACN) offers opportunities for conducting research to improve the safety of vehicles and improve the treatment of injured occupants. For the past five years the William Lehman Injury Research Center (WLIRC) and BMW have been conducting a pilot project to find ways to improve the service offered by ACN systems. This research also produces unique safety research opportunities. This paper deals with the added benefit of using the data from ACN calls for pioneering safety research.

By MY 2007 nearly 100% of the BMW's sold in the US will be equipped with an ACN system called "BMW Assist". The significance is that this fleet of BMW's will notify their Telematics Service Provider (TSP) when they have been in moderate or severe crash. This body of information will be of unprecedented value for research purposes. For example, researchers will be able to determine the time between the initiation of the emergency call and the arrival of rescue to further identify how to shorten the time and improve the service. In addition, cases with injuries can be identified as candidates for in-depth investigation. This capability will resolve one of the greatest impediments to crash investigation research – how to find crashes of interest. Finally, by having a complete census of all crashes in ACN equipped vehicles less than four years old, the crash exposure can be determined and injury risks can be accurately calculated. There is no other data system that will provide the resolution or accuracy of this system – particularly for the assessment of crash avoidance countermeasures.

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The paper will describe the methodology developed and summarize results of the pilot research using the ACN data. The paper will also present the methodology for analyzing the benefits of accident avoidance countermeasures.

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Technical Session: Motorcycle Safety

Paper No. 07-0018-W

Studying The Impact Of Using Motorcycle Leg Protectors On Reducing Accident Injuries

Afshin Shariat Mohaymany, Ali Eghbalian, *Iran University of Science and Technology, Iran*

Abstract:

The use of motorcycle and their accident rate has grown significantly in Iran in recent years. Due to the higher vulnerability of motorcycle riders the numbers of injuries in motorcycle accidents are higher than other vehicles (about 54%).

The most vulnerable part of body in motorcycle accidents is the leg; as in about 60 percent of motorcycle accident that cause injuries, leg injuries are perceivable. One of the accessories which can be helpful in reducing leg injury, are the motorcycle leg protectors, especially the front leg protectors. In this paper, collects data and information about the accidents that cause injuries and the number of injured motorcycles which are equipped with leg protectors and of those which are not, and also the rate of using the leg protectors in the community of normal motorcycle riders and those who have had injury accidents, is analyzed. The data has been gathered from available accident data, vehicle counts, and interview with motorcycle riders. For the purpose of statistical analysis of the data, graphical analysis and statistical tests, i.e. the likelihood-ratio test in two communities, and K-test, has been used. Additionally, Chi2 test has been applied for analyzing the results and examining the validity of the data.

Finally, it has been concluded that according to the existing statistics, it can not be inferred that installing the front leg protectors significantly reduces the rate of injury accidents. However, observations and surveys reveal that these protectors have a positive impact on reducing the leg injuries in non-severe motorcycle injury accidents.

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Paper No. 07-0091-W

MADYMO Simulation Study To Optimize The Seating Angles And Belt Positioning Of High Back Booster Seats

Rajiv Menon, Yoganand Ghati, Prashant Jain, *The Center for Injury Research and Prevention, The Children's Hospital of Philadelphia, United States*

Abstract:

Background: Data from the Partners for Child Passenger Study show that booster seat use among children ages 4-7 years has increased and its use is more beneficial in terms of injury risk when compared to vehicle seat belts. However, results from sled tests with a 6-year-old Hybrid III Anthropomorphic Test Dummy (ATD) in four different high back belt positioning booster seats (HBB) at a speed (56 km/h) higher than current compliance requirements (48 km/h) did not show corresponding benefits in some designs. Potential hypothesis for the apparent differences are 1) the lack of biofidelity of the ATD spine and neck 2) lack of high severity crash data from the field and 3) the possible differential performance of different HBB due to their design. A number of studies aimed at improving the biofidelity of the ATD have been done, but no study has looked at the differential performance of the HBB due to their design.

Objective: The Study objective was to use mathematical models to investigate and assess the Hybrid III 6-year-old ATD performance due to the variation in seating angles of a HBB and seat belt positioning across the ATD.

Method: Mathematical models of the HBB and FMVSS 213 bench seat were developed using the multi-body MADYMO software. The standard MADYMO 6-year-old ATD model was used to access the performance. This model was validated against a sled test and further parametric analyses were conducted. Parameters changed were the overall angle and the base angle of the HBB and the seat belt routing angle. The standard injury metrics (HIC, head and chest accelerations, Nij, and excursions) were used to quantify the ATD performance.

Results: The study demonstrated that by optimizing the ATD seating posture and the belt positioning across its chest, better ATD performance is achieved. An optimized angle of 5 degrees for base angle and 100 degrees for overall angle of the HBB, in combination with a belt angle of 40 degrees achieved better performance than the validated baseline model.

Paper No. 07-0127-W

The Development Of An Injury Cost Function For Child Passenger Safety

Chris Sherwood, Rob Marshall, Jeff Crandall, *University of Virginia, United States*

Abstract:

Research question: The design of the optimal child restraint environment must consider both vehicle system (VS) and child restraint system (CRS) components. The objective of this study was to analyze the

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contributions from each system for a rear facing child restraint (RFCR) involved in frontal crashes, in order to minimize the risk of child injury.

Methods: First, a technique was developed to evaluate the overall injury risk to a child based on existing injury risk curves and injury cost estimates to produce an overall injury cost. Second, a computational model of a 12 month old child in a RFCR was developed and used to assess the importance of VS and CRS parameters in frontal crashes using the overall injury cost.

Data sources: The overall injury cost was based on injury risk curves obtained from NHTSA and HARM 2000 injury cost estimates. The MADYMO model was validated against a sled test.

Results: Four variables (seat cushion, lower LATCH belt, restraint harness, and restraint cushion stiffnesses) were tested in a parameterized study which resulted in 625 simulations. The effects of each variable on the overall cost function were determined.

Conclusions: With the assumption that child excursion should be minimized, the analysis suggested that the vehicle seat cushion and lower LATCH belt should be designed with high stiffness values. Injury costs could be reduced by decreasing the CRS harness stiffness and increasing the CRS internal cushion stiffness values. The primary contributor to overall injury risk was the tension in the upper neck.

Discussion: This study provides a technique for quantifying the effects of different design components for a child seated in a RFCR.

Limitation of study: There are unavoidable estimates and simplifications in the injury risk curves and monetary estimates of injury levels. Continued research on pediatric injury tolerance is required to improve the injury risk curves. These findings should be confirmed with additional sled tests.

What does the paper offer that is new in the field?
The development of the technique for determining an overall injury cost function has not been applied to child occupants.

Paper No. 07-0186-W

Injuries To Children In Side Impact Crashes

Linda McCray, Mark Scarboro, *National Highway Traffic Safety Administration*
John Brewer, *Volpe National Transportation Systems Center, United States*

Abstract:
Children comprise more than 50% of the rear seat occupants in motor vehicle crashes. The National Highway Traffic Safety Administration has undertaken a study of real-world data to help characterize crash parameters and injury causation of children in side impact crashes. Although there is a paucity of

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data on children in motor vehicle crashes a detailed analysis of real-world crashes must be conducted to determine any potential safety improvements that can be afforded this population of rear seat occupants.

A query of the Crashworthiness Data System (CDS) shows that 12% of rear seat children in side impact crashes were unrestrained, while the Fatality Analysis Reporting System (FARS) shows that 45% of fatalities were unrestrained. A CDS query of side impact crashes with a change in velocity (delta V) of 30 kph or more was analyzed to determine what body regions were injured by contact with which vehicle component and with what injury severity. Children injured in side impact crashes of this intensity seem to exhibit a preponderance of head injuries in addition to those to the torso and extremities. Children on the near side in these crashes tend to suffer more severe injuries. Several case studies from the Crash Injury Research Engineering Network (CIREN) were examined. The cases involved children aged one to three years old who were injured in child restraint systems (CRS) appropriate for their age. Observations were made about the influence on injury severity of relative seating position (near side, center, far side), crash severity, structural intrusion, and attributes of the child seats.

Paper No. 07-0235-W

Four Years Of Enhanced Child Restraint Data Collection In NASS CDS

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Abstract:

In 2002, The National Highway Traffic Safety Administration's (NHTSA), National Automotive Sampling System (NASS) improved its child safety data collection. Each primary sampling unit (PSU), an initial crash data collection location, dedicated one data encoder to child safety issues. In turn, NASS data encoders took the PSU source data and created the CDS data entries. These CDS data were obtained via crash scene and vehicle inspections supplemented with occupant interviews and medical records, when these were available. Consequently, The NASS encoders were trained extensively on child safety seat technologies, as well as their installation and placement, and new variables and attributes were defined. The new variables and attributes allow encoders to fully describe the child safety seat within the vehicle during the crash. . The expanded data compiles real-world crashes involving child occupants providing a unique data set useful to NHTSA as well as the whole child occupant protection community.

This paper presents a description of the new data collection process, the new variables, and a first look at the analyses possible with the new data set.

Paper No. 07-0241-W

Review Of The Development Of The ISO Side Impact Test Procedure For Child Restraint Systems

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Abstract:
Side impacts are frequent and can pose a hazard for children travelling at the struck side in passenger cars. Although the number of seriously injured children has decreased during the last decades, there is still a considerable risk especially for head, neck and thorax injuries.
ISO TC 22 / SC 12 / WG 1 has been working on the definition of a side impact test procedure for child restraint systems for a number of years, taking into account other side impact test procedures for CRS already implemented in some countries.

The proposed paper is a comprehensive summary of accident data (from USA and Europe), boundary conditions to be recognised for the definition of a side impact test procedure for CRS (crash worthiness, geometry, etc.) and current side impact test procedures. Special emphasis is given to the design specification for a suitable test procedure with respect to loading conditions and test severity based on full-scale test data. The paper is based on a recent ISO Technical Report, which is a comprehensive base for the future ISO test procedure development.

Paper No. 07-0367-W

Implementation Of ISOFIX And LATCH Equipped Automotive Child Restraint Systems In An Aircraft Environment

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Abstract:
The increasing trend towards fractional aircraft ownership has seen a rise in the number of babies and children being transported on corporate and private aircraft. Occupant protection policies for children younger than 2 years on aircraft are inconsistent with all other national policies on safe transportation. Children younger than 2 years are not required to be restrained or secured on aircraft during takeoff, landing, and conditions of turbulence. The NTSB states that all occupants should be restrained during takeoff, landing, and turbulent conditions, and that all infants and small children should be restrained in an approved child restraint system appropriate to their height and weight.
Current FAA recommendations for child restraints are based on FMVSS and typically involve the use of child safety seats restrained by aircraft lap belts. Newer automotive restraint standards use the vehicle structure to restrain the child safety seat. These standards differ between North America (LATCH) and Rest of the World (ISOFIX). Development and testing to determine the optimum means of child restraint and a solution that works in both North America and Rest of the World is needed.

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Based on the results from the dynamic sled tests conducted in this project, there is sufficient data to conclude that the ISOFIX and LATCH system can solve the interface issues found in the past between the CRSs and the aircraft seats. Both the ISOFIX and the LATCH attachment methods offer similar level of safety for the 12 month and 3 YOLD occupants.
While this project provides an overview of the viability of the ISOFIX and LATCH system, additional research needs to follow in order to develop standards and recommendations.

Paper No. 07-0490-W

Revised Assessment Protocols And Scoring Methods For The Australian Child Restraint Evaluation Program

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Abstract:
A consumer information based child restraint evaluation program was initiated in Australia in 1992. A recent review of the assessment and evaluation procedures used in this program was undertaken and the assessment protocols and scoring methods have been significantly enhanced. This paper presents the revised assessment protocols and scoring methods currently being used in the Australian Child Restraint Evaluation Program. The program includes both a dynamic performance assessment and an ease of use assessment.

Dynamic assessment includes frontal testing (56km/h and 34g) and two side impact tests (90 degree, 32 km/h and 16g; and 66 degree, 32 km/h and 16g). The side impact test set up includes a non-intruding side door structure. Rearward facing, forward facing and booster seats are subjected to all dynamic tests using dummies corresponding to both the upper and lower mass ranges of design limits of each specific type of restraint. An approach based on an objective, pre-defined rating matrix was developed to score and rate the relative dynamic performance.

The ease of use assessment method is based on the North American methods used by ICBC and NHTSA. Some enhancements to the individual items assessed and the ratings used was made to suit Australian conditions. Details of these enhancements are presented.
A scoring system that allows for a four star rating system for both the dynamic and the ease of use performance was introduced and this is also presented and discussed in detail in this paper. Exemplar results from the first series of assessments conducted using the revised protocols are also presented to demonstrate the benefits of the revised protocol and the scope for further improvements to the methods being used.

The process for the release of the test results and the response from media are outlined.

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Technical Session: Advances in Truck and Bus Safety

Paper No. 07-0120-W

Japan's Approach Of Car To Truck Compatibility In Head-On Collision

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Abstract:
This paper shows the Japan's approach of car to truck compatibility in head-on collision accidents. It is thought that the Front Underrun Protection Device (FUPD) provided by ECE-R93 is effective to prevent car underride by head-on collision of a bonnet type passenger car vs. heavy truck. The meeting to formulate the FUPD regulation has been held by members from the government (MLIT), industries (JAMA, JABIA), and institute (JARI) since 2002. In this meeting, we agreed with the effectiveness of FUPD from statistics and results of full crash tests. It is thought that the passenger car driver fatalities can be decreased about 45% (36 people/year) by the heavy truck with FUPD.
FUPD is planned to the regulation of Japan at the end of 2006. The problem is whether or not to apply this regulated requirement to cement-mixer & tipper trucks as off-road vehicles. The off-road performance of the cement-mixer & tipper trucks decreases if it equips it with FUPD. However, it is difficult to recognize that the requirements don't apply to cement-mixer & tipper trucks, because these trucks were often driven on the urban area in Japan. We have eased the ground clearance of FUPD of the cement-mixer & tipper trucks to 450mm to strike a balance between off-road performance and the decrease in aggressiveness. The FUPD of 450mm in height would decrease 29% of the passenger car driver fatalities.

Paper No. 07-0124-W

Crash Tests To Assess The Secondary Safety Of A Large MPV

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Abstract:
Multi Purpose Vehicles (MPVs) have gained great popularity for many years. But up to now there ar still lacks of published results showing the crash test performance of such vehicles.
To assess the secondary safety of the large MPV Mercedes-Benz Viano, DEKRA conducted 3 crash tests according to the Euro NCAP test protocols: a 64-kph-40-%-ODB frontal crash, a 50-kph-MDB side impact and a 29-kph-pole side impact. The tested model was a 2005 Viano 2.0 CDI Trend with long wheel base (3,200 mm) and a kerb weight of 1976 kg.
The paper describes the tests and the tested vehicle with its relevant safety features. The test results are shown with special attention to the dummy loads and their assessment including modifiers according to the Euro NCAP protocol. The overall rating of the vehicle is 5 stars for adult occupant safety and 4 stars for child protection. With this background the articles gives also new information on what is state-of-the-art for secondary occupant safety in this vehicle class.

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Paper No. 07-0212-W

Volvo Trucks Field Operational Test: Evaluation Of Advanced Safety Systems For Heavy Trucks

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Abstract:
A field operational test (FOT) was recently completed to determine the potential safety benefits of advanced collision avoidance systems for heavy trucks. The safety systems in the FOT included a forward collision warning system (CWS), adaptive cruise control (ACC), and electronically controlled disc brakes. These systems were developed to reduce the frequency and severity of rear-end collisions, which accounted for 28% of all crashes involving heavy trucks in 2003. NHTSA managed the FOT which was funded under USDOTs Intelligent Vehicle Initiative (IVI). The industry team that conducted the test was led by Volvo Trucks North America. Battelle performed the independent evaluation.

Beginning in January 2001, 100 trucks were placed into service with US Xpress (fleet) and operated in normal revenue-generating service throughout the 48 contiguous United States. The paper presents findings based on engineering analysis of data collected from onboard vehicle data acquisition systems, as well as operational data from Volvo warranty files, US Xpress accident files, and vehicle brake component wear measurements. Additionally, advanced safety system durability, reliability, operational cost, and driver acceptance are evaluated.

A statistically significant, 28% reduction in rear-end crashes associated with the deployment of the three systems bundled together was found, although the majority of this benefit (21%) comes from the effect of CWS. A known limitation of the safety benefit calculation is that the statistical uncertainty of the estimated crash reduction rate varies as the level of the conflict definition changes. The paper includes a detailed discussion of the results when analyses are done at six different levels of conflict definition.

According to driver surveys, most drivers agree all three technologies help them drive more safely. Over 80% of drivers prefer trucks equipped with CWS, and over 90% prefer trucks equipped with ECBS. The perceived safety benefit is supported by the data, as drivers using the CWS tended to maintain greater following distances than drivers without the system.

Paper No. 07-0237-W

Study Of Driver Performance/Acceptance Using Aspheric Mirrors In Light Vehicle Applications

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Abstract:
Purpose: This paper will inform the reader about the research questions, experimental design, and test methodology of the subject research.

Content will be organized as a synopsis of the following points: Research questions, Problem size and justification, System development history, Requirements determination, Mapping of the experimental design to research questions and of the research questions to specific analyses, Discussion of measuring the relative performance of candidate mirror systems, Progress of static and dynamic testing, Scientific and safety contributions, and Future work

Advances in mirror technology have motivated the need for revisiting the question of how drivers use those mirrors while driving. Blind spots are the common complaint of mirrors, and new designs have appeared in the U.S. and European markets to help improve overall visibility. This research is the first comprehensive study of how drivers perform and accept various combinations of left and right mounted planar, convex, and aspheric mirrors. In addition, this research expands the basic factorial design to examine the effect of mirror frame size, which is known to dramatically change the quality and quantity of field of view. Whereas, existing Rules specify the minimum mirror area for passenger vehicles, there is evidence that indicates the performance of the mirror can be significantly improved per unit area size increase. Optimal mirror size may positively interact with previously rejected mirror characteristics, thereby affording a superior net improvement. This paper reports the work in progress, including the most research issues and activities completed just prior to data collection.