



# 충돌안전 & 승객보호



## 모듈러 아키텍처 기반의 전동화 모듈 충돌 평가 방법 개발

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### Development of Collision/Safety Evaluation Methodology for System Level of Electrified Module Based on Modular Architecture

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**Key Words** : Full cell electric vehicle(수소연료전지차), Protocol(프로토콜), Modular architecture(모듈러 아키텍처)

#### ABSTRACT

Today, collision/safety assessment standards of commercial electrified vehicle is not setup. Automotive makers have developing design methods using modular architecture method to solve design complexity.

Throughout this study, commercial FCEV vehicle collision/safety assessment process is established and hope to has been demonstrated to be useful to develop a more optimized design in consideration of Fire/High-voltage safety. We get the information where is the most sensitive evaluation criteria in using the process to raise the safety. Existing crash safety development methodology has limitations and may have changed to a difficult environment where the safety of the vehicle is to be guaranteed by the manufacturer in an unformatted crash condition. It takes a lot of time and effort to test vehicle with full system again and again. A second-best solution is to make use of component system level testing. This solution is collision/safety assessment test methodology for module unit based on modular architecture.

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## Far-side 충돌 시 안전벨트 설계 변수의 승객 상해 민감도 분석

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### Sensitivity Analysis of Seatbelt Design Parameters Affecting Occupant Injury in Far-side Impacts

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**Key Words** : Far-side impact(Far-side 충돌), Three-point seatbelt(3점식 안전벨트), Occupant safety(승객 안전), Human body model(인체모델), Injury risk(상해 위험도)

#### ABSTRACT

Far-side impacts have only recently been addressed by safety regulations and assessment protocols, such as those of NHTSA and the Korean NCAP, in contrast to other well-established impact conditions (e.g., frontal or side impacts). Despite this late inclusion, far-side impacts account for a significant proportion of severe and fatal injuries. Real-world crash investigations consistently highlight the vulnerability of occupants—particularly the head and thorax regions—under far-side impacts. In response, Euro NCAP introduced a dedicated far-side impact assessment protocol in 2020 to better evaluate occupant protection.

This study investigates the influence of three-point seatbelt design parameters on occupant kinematics during far-side impacts. Using the Euro NCAP far-side sled model with the GHBMCM50-OS human body model, we validated simulation results against Post-Mortem Human Subject (PMHS) data under identical conditions. The analysis varied the Z-axis positions of the D-ring and buckle, and the X-axis positions of the buckle and lap belt anchor, producing 81 simulation cases. Injury risks were quantified across these cases, and sensitivity analyses identified which parameters most significantly affected occupant injury outcomes. These findings allow for effective restraint system optimization to reduce injury risk in far-side impacts.

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## 정면 충돌 시 차량의 연식에 따른 승용차량 탑승자 손상 중증도 비교

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### Comparison of Injury Severity of Passenger car Occupants According to Car years in Frontal collisions

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**Key Words :** Car years(차량연식), Frontal collision(정면충돌), Passenger car(승용차), Injury Serverty(손상중증도)

#### ABSTRACT

The purpose of this study was to investigate the association between car years and injury severity among passenger car occupants in frontal collision. It also examined whether older vehicles are associated with an increased risk of severe injuries.

Passenger car were categorized into two groups according to model year: vehicres manufactured in 2010 or earlier and those manufactured in 2011 or later. In frontal collisions, occupants were further classified based on seat belt use (Yes, No, Unknown). Injury severity was evaluated using the Injury Severity Score(ISS) and the Maximum Abbreviated Injury Scale(MAIS). Independent samples t-tests were conducted to examin whether there were significant differences in injury severity betwnn the grops, in order to clarify the association between car years, seat belt use, and injury outcomes

The analysis revealed that occupants in vehicles manufactured before 2010 sustained significantly higher injury severity compared with those in vehicles manufactured after 2011. This difference was most pronounced in frontal collisions without seat belt use, where both ISS and MAIS were markedly elevated. Among belted occupants, the protective effect of seat belts was ovserved regardless of car years, although older car still sdhowed slightly higher injury severity.

In addition, CDC codes reflecting greater deformation extent and intrusion were strongly associated with higher ISS and MAIS. These findings suggest that both car years and crash characteristics in fluce injury severity, and that the combination of seat belt non-use and older vehicle models substantially increases the risk of severe trauma

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## 실사고 기반 충돌 안전성 평가를 위한 시뮬레이션 기법 개발

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### Development of Simulation Techniques for Real Field Accident-Based Crash Safety Evaluation

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**Key Words :** Integrated safety(통합안전), Madymo(마디모), Ls-dyna(엘에스다이나), Equivalent crash model(등가충돌 모형), Crash event scenario(충돌사고 시나리오), Car-to-Car crash(차대차 충돌), Virtual vehicle development(버추얼차량개발), Roll over(전복사고), Human body dummy(인체모형더미).

#### ABSTRACT

This paper introduces a collision simulation methodology that describes a real-filed complex collision scenario and introduces the results of research on injury patterns in complex collisions using full size human body dummy for crash simulation.

실사고 시나리오 기반의 복합충돌 사고 시뮬레이션은 기존의 정형화된 NCAP 이나 법규 시험모드와는 다르게 시나리오 자체가 매우 길다. 예를 들면 고속 정면 고정벽 충돌 시험의 경우 시뮬레이션 시간이 짧게는 100ms 길게는 300ms 정도면 모든 이벤트가 끝이 나지만 정면 풀 충돌 등의 1차 충돌에 이은 2차 전복까지의 시나리오라면 짧게는 2,000ms에서 길게는 4,000ms까지 진행되므로 슈퍼 컴퓨터 연산 시간이 그만큼 기하급수적으로 늘어날 수 밖에 없다. 때문에 충돌 해석 시뮬레이션을 계획할 때 좀 더 효율적인 방법론이 필요하다. 더불어 정면충돌, 측면 충돌 하는 식으로 충돌의 방향이 정해져 있다면 정면용 더미, 측면용 더미를 그때 그때 맞춰서 사용하면 되지만 충돌 방향이 정해져 있지 않은 실사고 충돌 시나리오에 더해 전복 현상까지 진행이 된다면 사용해야 되는 더미 선택에 대한 이슈도 있다. 본 논문에서는 이러한 문제점 해결을 위해 실사고 복합 충돌 시나리오에 걸맞는 효율적인 충돌 시뮬레이션 방법론 소개와 함께 일반적인 충돌용 더미가 아닌 인체를 그대로 묘사한 휴먼 바디 인체더미를 사용하여 복합충돌시 발생하는 상해 패턴에 대한 연구 결과 소개 및 이러한 기법을 실제 차량 개발에 어떠한 방식으로 적용하여 차량의 안전성을 높이고 있는지 간략히 소개해 보고자 한다.

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## 수납형 스티어링휠 조건 안전장치 시나리오 연구

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### A Study on Safety Device Scenarios for Retractable Steering Wheel Conditions

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**Key Words :** Retractable steering wheel(수납형 스티어링휠), Autonomous driving(자율주행), Driver airbag(운전석 에어백)

#### ABSTRACT

With the commercialization of Level 4 and higher autonomous driving systems, steering wheels may be retractable during driving to enhance occupant comfort. However, when the steering wheel is stowed, the distance between the driver and the wheel increases by approximately 200 mm, potentially compromising occupant protection performance in the event of a collision.

This study investigates safety device solutions applicable to scenarios where the steering wheel is retracted and aims to identify the optimal alternative. Three feasible scenarios were first derived, followed by the design and evaluation of a novel airbag system tailored to each. Based on these evaluations, a new concept for a driver airbag mounted on the dashboard was proposed. Deployment tests confirmed that this airbag provides a protection area equivalent to that of conventional driver airbags within the same deployment time.

Furthermore, in the stowed steering wheel condition, the proposed airbag can be deployed simultaneously with the conventional driver airbag, effectively filling the additional space between the occupant and the airbag. This suggests that the proposed system can maintain equivalent protection performance even in future autonomous vehicle layouts.

Through this research, a foundational direction for designing safety devices in future vehicle interiors with retractable steering wheels is presented. Further studies will evaluate the applicability of the proposed system across various crash modes.

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# Efficient Prediction of Passenger Chest Injury Distributions Using Surrogate Modeling Under Uncertainty Variables

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**Key Words :** Finite element analysis(유한요소해석), Surrogate model(서로게이트 모델), Gaussian process(가우시안 프로세스), GHBM(C(Global Human Body Model Consortium)), Uncertainty Quantification(불확실성 정량화)

## ABSTRACT

Real world crashes involve a range of uncertain factors such as occupant posture and restraint-system configuration. With emerging technologies such as autonomous driving enable more flexible passenger postures, addressing the increased variability and uncertainty in posture and restraint conditions becomes critical. For injury assessment in real-world crashes, we need to use a human body model (HBM) due to its higher biofidelity than anthropomorphic test devices. HBM based crash simulations are yet highly computationally expensive, which makes extensive parametric exploration and continuous injury quantification across crash scenarios difficult. To address this, we employ surrogate modeling to quantify occupant injury across diverse crash conditions. First, we build a frontal sled model using the GHBM M50-OS model. We then generate 25 parametric models by varying two design variables: occupant posture and D-ring Z position at five levels each, and simulate them to obtain chest deflection as the output. Using these cases and their corresponding outputs, we train a Gaussian Process surrogate model to predict chest deflection and use an adaptive sampling scheme to improve accuracy. The proposed method performs continuous injury prediction across diverse crash scenarios using only a finite set of simulation runs. Consequently, we quantitatively characterize continuous injury responses over a diverse set of cases.

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## 근접 측면 충돌 조건에서 여성 인체모형의 생체모방성을 고령자 기증자와 비교 평가

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### Assessing the Biofidelity of 5th Percentile Female ATDs Against Elderly PMHS in Near-Side Impacts

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**Key Words :** Elderly PMHS(고령기증자), Thoracic injury(흉부상해), Near-side impact(근측면), ATDs(인체모형더미).

#### ABSTRACT

Small, elderly females have been identified as a highly vulnerable demographic in motor vehicle crashes and are particularly susceptible to severe thoracic injuries in near-side impacts. For decades, the biomechanical data used to develop safety standards has often been derived from unrealistic test conditions that fail to capture real-world crashes, or from data scaled down from mid-size males using an approach that overlooks key sex differences. This study evaluates whether current 5th percentile female side impact ATDs can accurately replicate Post Mortem Human Subject (PMHS) responses and predict injury in a realistic near-side impact scenario. The biomechanical responses of five small, elderly female PMHS were compared to those of the SID-IIs and WorldSID-05F in a realistic 50 kph near-side impact test. The experimental setup recreated the occupant environment, including a mass-production vehicle seat, a side-impact airbag, a standard three-point restraint with a pretensioner, and simulated door intrusion. Both PMHS and ATD were extensively instrumented with chestbands to quantify chest deflection. Spinal kinematics were recorded and ranked using the Biofidelity Ranking System (BioRank) to assess biofidelity of the ATDs during the event. The ATDs demonstrated biofidelic spinal kinematics (BioRank < 2.0). However, significant differences were found in thoracic response. While anterior-posterior chest deflection was similar, the ATDs failed to match the lateral chest deflection of the PMHS (e.g., PMHS:24.4±10.6mm vs. SID-IIs:56.3mm and WorldSID-05F:5.2mm), leading to an inaccurate prediction of thoracic injury risk by the ATDs. The discrepancy in thoracic response suggests that current injury metrics for side-impact ATDs are insufficient for realistic near-side impact scenarios involving combined loading from modern restraint systems. Updated Injury Assessment Reference Values (IARVs) are necessary to accurately predict injury risk for small female occupants.

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