A development of the CAE process for the AEB-occupant integrated safety system

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ABSTRACT

The individual performance development of an active safety system and a passive safety system may lead comprehensive safety performance insufficient possibilities in the scenario of a variety of collision. The independently developed active safety systems and passive safety systems result in the lack of passenger protection performance when a collision accident is occurred. In order to complement this, the sharing of the collision prediction information or the optimization of the active/passive safety systems should be conducted for the injury reduction of passengers. The integrated CAE process for AEB, ASB (Active Seat Belt) and the airbag system is composed of the four major components such as a sensor model, traffic simulation model, vehicle dynamics model and occupant simulation model. In cooperation with each component, the deceleration characteristics of the vehicle are extracted at the time of AEB operation in certain traffic conditions. By utilizing the extracted vehicle deceleration characteristics, the kinematics analysis of passengers can be carried out. Moreover, the injury of the passenger at collision accident after the emergency braking can be simulated and the reduction of injury can be achieved by the activation of the restraint system before collision accident. Pre-crash seat belts or active seat belt reduce the forward movement of passengers by activating a seat belt retraction before the collision. Neck extension moment and neck shear force reduction effect through the reduction of forward movement can also be expected. In this study, coupled simulation of the ASB control logic and MADYMO occupant simulation model is developed in order to adjust the seat belt retraction strength before collision. A scenario is modeled for a situation of applying a 1g brake with an initial velocity of 80 km/h to simulate a 56km/h full frontal crash to stationary vehicle in real world. The initial dynamic behavior or movement of the vehicle before crash is simulated by using the integrated active-passive safety simulation model. This simulation result data is used as initial conditions of MADYMO occupant simulation. The analysis of injury reduction effect was performed by the belt retraction control of the ASB. The AEB simulation environment is developed by using the MATLAB / Simulink, CarSim and PreScan. The EuroNCAP AEB assessment scenario-based vehicle test data were compared with the results of MiLS. It is possible to obtain vehicle deceleration results similar to the actual vehicle test. Using the deceleration data of the vehicle during emergency braking through the AEB simulation, it was possible to predict the posture change in the passenger. Coupled Simulation between the ASB and passenger model can simulate the posture control of the passenger by the ASB control. It is possible to confirm the positive effect of injury and kinematics of passengers due to the presence or absence of ASB function. The present study can be used for prediction of the passenger kinematics caused by AEB activation and for the study of the restraint system in order to reduce the injury during forward collision after emergency braking.

Background

AEB (Autonomous Emergency Braking) is a representative active safety device fitted to prevent the avoidance of frontal collision and mitigating severity severity. During the AEB operation, conducting a frontal impact on the AEB operation for AEB mounted frontal collision mitigation, the results of the Daimler Research and Development Study were estimated to account for about 30 % of the total impact on the overall collision in the German fleet. In NHTSA's study, the overall collision rate was estimated at about 35 % of the total impact on the AEB, mitigating the possibility of mitigating the accident. Thus, the AEB has an obvious advantage in reducing the impact velocity, but the driver should be considered to optimise the safety of all of the passengers, and to optimize the safety of all of the scenarios that result from the application of the AEB due to the application process of the stability of the safety system. In the ASSESS (Assessment of Integrated Vehicle Safety Systems) project, the impact of crash performance assessment and system effectiveness was conducted in the event of crash performance assessment and system effectiveness. In the study, the reduction of the vehicle's kinetic energy by decreasing the deceleration caused by the reduction of the vehicle's kinetic energy in the event of a collision occurred in the event of a collision, but the neck injuries indicated overall increases in the overall result. The low crash velocity caused by the pre-crash brake actuation has confirmed that the vehicle occupant has reduced the biomechanical injury values of the vehicle occupants. This effect was observed in all tests conducted on the ASSESS project, but the operation of the pre-crash pretensioner was less effective than the pre-crash brake application. In a collision test of a full scale, the low impact velocity of the brakes resulted in a positive impact on the body intrusion and vehicle structure, but the movement of the occupant's forward movement affected the negative effects of the vehicle. It was judged that the shear force of the neck was more clearly influenced by this phenomenon.In addition, variability in passenger behaviour was observed. As a result, the impact of the driver's injuries increased by approximately 40 % in the crash of the driver's seat after the collision of the AEB operation.This is determined by the consequence that the restraint is not optimized for the collision situation after the emergency braking. The ASSESS Project assumes that the operation of the pre-crash pretensioner and the forward action of the dummy have adversely affected the interaction between the airbags and the dummy. In Japan, a collision research after the operation of the AEB was conducted by using the deceleration sled. During normal seat belt application tests, the driver's neck injury was closer to the limit of the regulation, but the forward movement of the dummy has reduced during pre-crash pretensioner seat belt application tests. In the event that the active safety system and passive safety systems are individually develpoed, the overall safety performance in various crash scenarios may be deficient. Active, passive safety systems that are developed independently may undergo deterioration in the occupant protection performance after the activation of the active safety equipment activated. In order to supplement this, it is possible to reduce passenger injury by optimizing the operation of the passive safety equipment between active and passive systems and the actuation of passive safety equipment associated with the active safety system. In this study, an integrated analysis process for the AEB, ASB and air bag systems that correspond to Crash and Crash situations was deployed. Following the AEB operation, the optimum qualification and operation of the ASB to reduce passenger forward movement and passenger injury in the collision scenario is performed. It is expected that this study will enable the study of the occupant behavior of the AEB braking scenario and the study of the AEB braking profile considering the occupant's behavior in the event of an accident.

MiLS (Model in the Loop Simulation)

An integrated analysis process for the AEB, ASB (Active Seat Belt), and an airbag system is configured using the following components in the figure1.

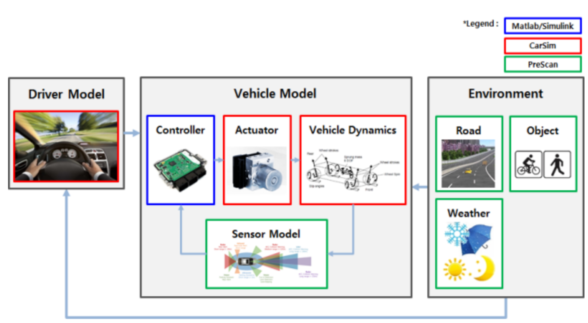


Figure 1.MiLS Configuration diagram

Connect each component to extract the characteristics of the vehicle deceleration characteristics in the particular traffic scenario. Behavior Analysis of passengers aboard the vehicle can be performed by using the extracted deceleration of the vehicle. Passenger injuries were predicted in the collision accident after AEB activation and the restraint device combination was used to optimize injury improvement. MiLS is a method to verify the system and verify the design specifications through the model based design (MBD, Model Based Design) when the design specification is derived at the initial stage of system development. The core elements of the MiLS for ADAS development and verification consist of a vehicle dynamics model, an environmental model, an object model, a sensor model, and a driver model. In this study, we modeled the controller (AEB) through Matlab / Simulink, the driver, the vehicle model, the actuator with CarSim, the sensor and the driving environment model with PreScan.

Vehicle Dynamic Model

In this study, we model the mass - production vehicle model with CarSim, a vehicle dynamics programming tool. CarSim is software that can simulate and analyze the dynamic behavior of a vehicle on a three-dimensional road surface. If the user sets the basic geometry of the vehicle, the power train, the road surface condition, the driving condition, etc., CarSim calculates and simulates the driving situation of the vehicle. CarSim has various input and output parameters, which makes it easy to integrate with Matlab / Simulink in controller configuration. Also, preprocessing and post-processing can be executed in GUI environment, and it has the advantage of fast calculation speed.

Sensor Model

The AEB logic of this research performs control based on the data measured from the radar sensor and the camera sensor. Therefore, we have to model radar and camera sensors and use TASS's PreScan for this. The radar sensor was modeled through the Radar Sensor Model of the Detailed Sensor provided by PreScan. The detailed sensor simulates the data reflecting the shape information of the 3D model of the object being measured. Since the radar sensor can simulate the damping ratio according to the distance of the object measured through the AGM (Antenna Gain Map) including the shape information, it is possible to implement a similar model to the actual radar sensor. The figure below shows the AGM (Antenna Gain Map) of the Radar Sensor.

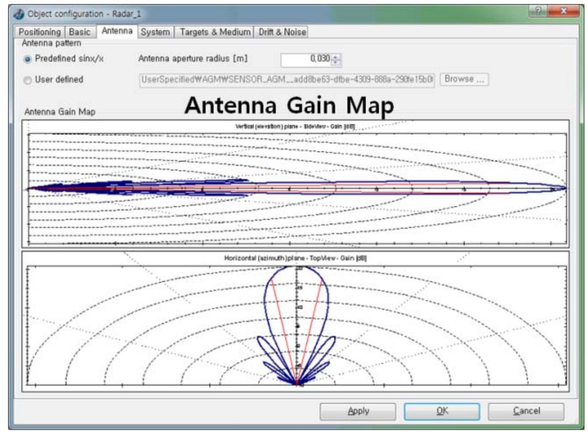


Figure 2. Antenna Gain Map (Radar Sensor)

The camera sensor is modeled through OCS (Object Camera Sensor) of Ground-truth sensor provided by PreScan. OCS is a sensor that is effectively used when the image processing part is not included in the algorithm to be simulated. In the case of OCS, relative speed and relative distance information of the preceding vehicle can be obtained without image processing.

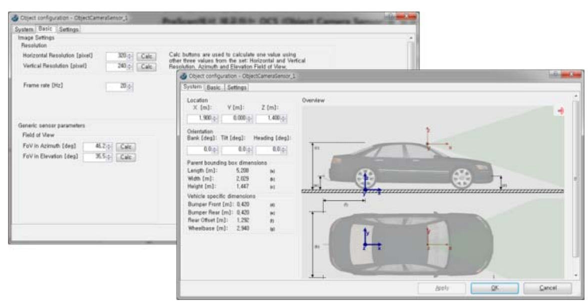


Figure 3. Camera Sensor configuration

Target Vehicle Model

In order to implement AEB logic, a target vehicle is required. Since the preceding vehicle does not need the implementation of Vehicle Dynamics, it implements the driving situation through the Speed Profile. In case of CCRm (Car-to-Car Rear Braking) scenarios, the speed of 20km / h is set for the EuroNCAP scenario. For the Car-to-Car Rear Braking (CCRb) scenario, it is set for each deceleration.

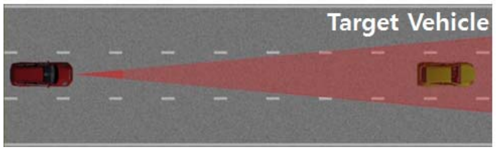


Figure 4. Target Vehicle Model

Establish environment for AEB scenario

In this study, we use the automatic emergency braking scenario based on EuroNCAP to verify the AEB logic. The AEB verification scenario environment was constructed through PreScan. The scenarios are divided into Car-to-Car Rear stationary (CCRs), Car-to-Car Rear moving (CCRm), and Car-to-Car Rear braking (CCR). Each detailed condition is based on EuroNCAP AEB Car-to-Car scenario. The AEB logic was verified through a total of 18 scenarios for the AEB analysis model.

Analyze AEB Simulation Results

The simulation environment for AEB algorithm verification is composed as shown below.

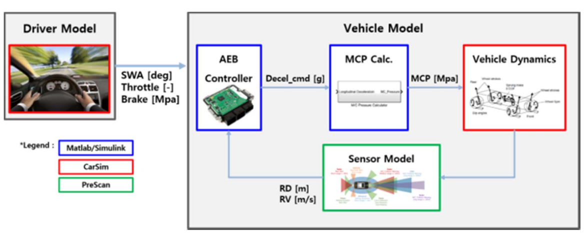
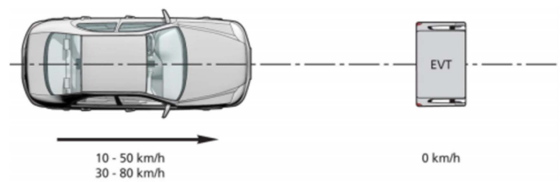


Figure 5. Configuring the AEB simulation environment

Since the Actuator is required to follow the required deceleration corresponding to the output of the AEB algorithm, the required deceleration is converted to the master cylinder pressure in units of MPa using the vehicle dynamics equation. The converted master cylinder pressure was input to the Carsim braking system to perform braking.

CCRs Scenario

In the case of the CCRs scenario, the car is traveling toward the rear of the Euro NCAP Vehicle Target (EVT), which is stopped at a speed of 10 to 80 km / h. The tests were conducted for 20km / h, 30km / h, 40km / h and 50km / h scenarios. For each scenario, it is confirmed that the simulated results are similar to the actual vehicle test results. Figure 7 shows simulation results of CCRs RV = 50 km / h and comparison of actual vehicle test results.



	CCRs			
	AEB + FCW combined		AEB only	FCW only
	AEB	FCW		
AEB City	10-50 km/h	-	10-50 km/h	-
AEB Inter-Urban	-	30-80 km/h	30-80 km/h	30-80 km/h

Figure 6. CCRs Scenario

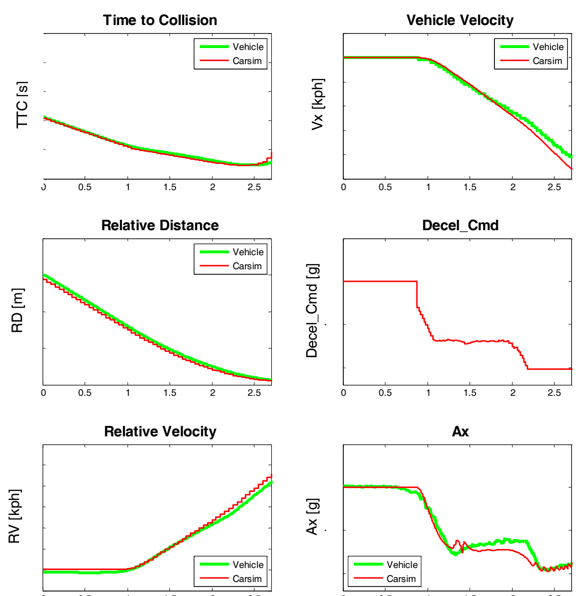
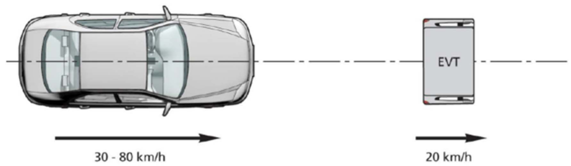


Figure 7. Comparison of CCRs RV = 50km / h simulation and actual vehicle test results

CCRm Scenario

In the case of the CCRm scenario, the subject vehicle travels toward the rear of the Euro NCAP Vehicle Target (EVT), which travels at a constant speed of 20 km / h at a speed of 30 to 80 km / h. In the case of the actual vehicle test, the test is performed for 70km / h and the verification is performed for the scenarios of 10km / h, 20km / h, 30km / h, 40km / h and 50km / h. As a result, it was confirmed that the depreciation rate of the simulation result tends to be lower than the actual vehicle test result. However, the overall simulation results are similar to the CCRs simulation results.



	CCRm			
	AEB + FCW combined		AEB only	FCW only
	AEB	FCW		
AEB Inter-Urban	30-70 km/h	50-80 km/h	30-80 km/h	50-80 km/h

Figure 8. CCRm Scenario

CCRb Scenario

In the case of the CCRb scenario, the EVT is decelerated to 2 m / s ^ 2 and 6 m / s ^ 2, respectively, while the vehicle and the Euro NCAP Vehicle Target are traveling at constant speed with an initial relative distance of 12 m and 40 m, respectively.

Co-Simulation of ASB (Active Seat Belt) logic and occupant simulation

A pre-crash seat belt or an active seat belt can reduce the forward movement of passengers by pulling in the seat belt before the collision and reduce the necking moment or neck shearing force by reducing the forward movement. In this study, an analytical model is constructed to control the pull - in strength of seat belt before collision by interlocking ASB control logic and MADYMO which is S / W for analyzing passenger behavior.

Analysis of ASB effectiveness

In order to analyze the ASB effectiveness, we analyzed the injury scenario according to the presence of ASB in the crash scenarios after deceleration to 40kph during 56kph driving. Driving and crash scenarios are shown figure 10.

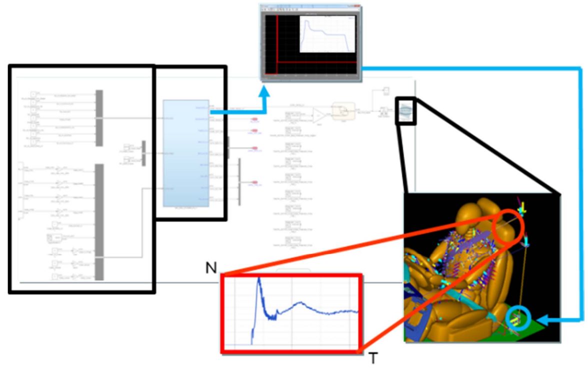


Figure 9. Co-Simulation of ASB (Active Seat Belt) logic and occupant simulation

Figure 10. Driving and crash scenarios

As shown in the graph below, the injury rate for these conditions is reduced by 62% when ASB is operated.

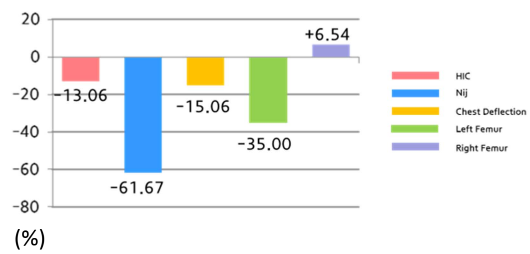


Figure 11. Rate of injury increase / decrease with ASB

In the dummy posture at the time of collision, the ASB frontal behavior control effect can be confirmed, and the forward mobility reduction can be confirmed even in the posture comparison at 50 ms after the collision.

In this paper, we analyze the effect of ASB on the reduction of injury by controlling the belt pulling load by constructing the collision scenario after decelerating to 56kph by braking during 80kph braking using the deceleration rate data extracted from the AEB analysis. We used the scaling of the total load and the scaling method of the section. Neck injury tended to decrease when the load was increased, but chest injuries tended to increase.

Overall injuries were predicted to be equivalent. As a result, it was confirmed that the improvement rate of the comprehensive injury was not large in the loading area which can be increased by the present ASB specification, and the improvement of the injury according to ASB was expected.

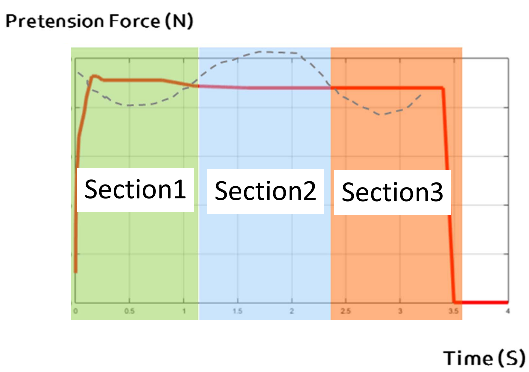


Figure 12. Inlet Load per section

CONCLUSIONS

AEB, Active Seat Belt (ASB), and Airbag System (Virtual Tool Chain) are built to extract vehicle deceleration characteristics when AEB is operated in a specific traffic scenario and ride on the vehicle using extracted deceleration characteristics analysis and analysis of the behavior of passenger were carried out. In case of collision after sudden deceleration, the degree of injury of passengers was predicted, and the effect of injury reduction in applying active seat belt was confirmed. The following conclusions were obtained.

(1) The MiLS concept was applied to AEB analysis. MiLS developed the system to satisfy the design specification through model based design (MBD, Model Based Design) at the early stage of system development.

(2) Simulation environment of AEB logic is built by integrating MATLAB / Simulink (controller model), CarSim (vehicle and actuator model), PreScan (driving environment and sensor model) and utilizing the actual vehicle test data based on EuroNCAP AEB verification scenario , MiLS results, and the consistency after the verification. In addition, we verified the consistency with the actual vehicle test and obtained the same deceleration results as the actual vehicle test.

(3) AEB analysis was used to predict the posture change during braking by using the vehicle deceleration rate data during braking.

(4) Through the co-simulation between the ASB and the occupant analysis model, it was possible to implement the passenger attitude control according to the ASB control, and it was confirmed that the passenger injury and the behavior improvement by the ASB operation were improved.

(5) In this study, predictive analysis of passenger behavior connected with AEB operation scenario is possible, and it is expected that it can be used in AEB braking profile study considering occupant behavior and prediction of passenger behavior, restraint device for injury reduction in case of crash, and passenger behavior do.

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